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SPATIAL DISTRIBUTION OF MALARIA INDICATOR IN TANZANIA

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SPATIAL DISTRIBUTION OF MALARIA INDICATOR IN TANZANIA

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SPATIAL DISTRIBUTION OF MALARIA INDICATOR IN TANZANIA

ABSTRACT

Malaria is a serious health threat in the World, mostly in Africa, where it has been estimated that 90% of the world's cases occur (WHO, 2008). In Tanzania, close to 93% of the 34.4 million inhabitants are at risk of contracting the disease (PMI, 2005). According to (Tanzania-Ministry of Health, 2008) the number of morbidity and mortality among outpatient and inpatient admissions accounts for up to 40 percent.

The aim of this work is to generate useful spatial information to support decision making concerning malaria control and monitoring in Tanzania.

Several multi-scale maps and graphics showing the most affected areas and associated indicators which are favorable to mosquito densities through analyzed data are shown, and suggestions focused on that analysis are given.

The results have shown that the households with bed nets for sleeping, those who are spraying against malaria and those who are using insecticide mosquito bed nets are at low risk of contracting malaria disease.

KEYWORDS

Malaria Epidemic

Spatial Distribution

Spatial Overlay

ACRONYMS

BS ve+- Infected blood with Malaria *Plasmodium*

EDH- Ethiopia Demographic Health

GIS - Geographic Information System

IRS- Indoor Residual Spraying

MOH- Ministry of Heath

NBS- National Bureau of Statistics

NPTN- National Pesticide Telecommunications Network

PMI- Presidents Malaria Initiatives countries

SDI- Spatial Data Infrastructure

USA- United States of America

WHO - Word Heath Organization

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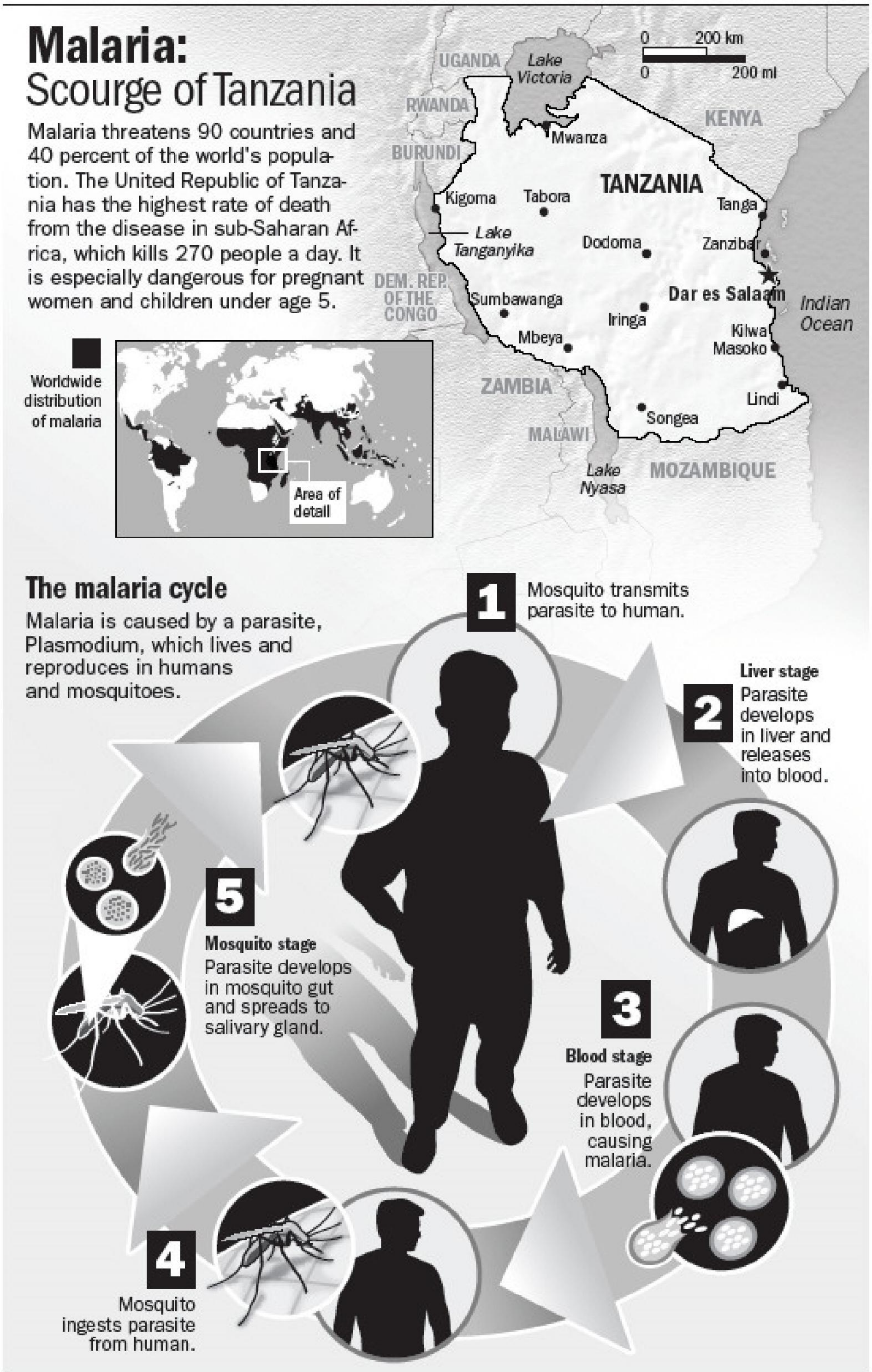

Figure 1. Disease transmission and Malaria (*Plasmodium spp*) life cycle. (Source: CDC, WHO, Johns Hopkins Blooming School of Public Health).

1 INTRODUCTION

Malaria is more pronounced in developing countries and in populations living under the most difficult and impoverished conditions. The disease causes damage by weakening the health and general welfare of families. Through endangering the survival and education of children; it debilitates the active population and impoverishes individuals and countries. The treatment of the sick people calls for more on the national budget, an extra burden that hinders other aspects development. For example, the state budget allocated for the control of malaria disease turns to compromise other developmental project especially for a developing country such as Tanzania. Malaria problems vary enormously from country to country, from area to area and even within different groups of the population (Connor *et al,* 2006) in Figure 1 show the desease transmission and malaria (*Plasmodium spp*) life circle.

The disease is caused by four species of *Plasmodium* parasites that are transmitted by the female *Anopheles* mosquitoes (Figure 2) through bites. The predominant species is *Plasmodium falciparum* of the four (*Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale*, and *Plasmodium malaria*) that cause human malaria, *Plasmodium malaria* is the most dangerous. Malaria causes an estimated 2.7 million deaths per year, with most of these deaths occurring in Africa (PMI, 2005). About 90% of the world's malaria cases occur in Africa (WHO world, 2008).

Figure 2. Aspect of *Anopheles sp*. mosquito, vector of Malaria disease

In Tanzania, *Plasmodium falciparum* is the most common (Tanzania HIV/AIDS and Malaria indicator Survey, 2008). This species causes severe malaria, and is fatal if not diagnosed early or treated adequately. The most severe cases occur among persons who have not yet developed sufficient immunity to malaria through previous exposure. Children under the age of five are at the highest risk, many children who survive an episode of severe malaria may suffer from learning impairment or brain damage. Besides the young children are pregnant women because of their reduced natural immunity (Connor *et al*, 2006). Pregnant women are four times as likely to experience the complications of malaria as compared to non-pregnant women. In the extreme cases malaria may cause loss of pregnancy among women, low birth weight, and neonatal mortality (Jamison *et al,* 1993).

Malaria is a major public health concern for all Tanzanians, especially for pregnant women and children under age five (Tanzania HIV/AIDS and Malaria indicator Survey, 2008). This highlights the importance of this study whose result may reveal facts on how the disease could be controlled spatially.

Many parts of the country, including the uplands, report malaria transmission occur throughout the year although it occurs more frequently during and after the rainy season (beginning from April to May) and during the farming season in the country, Approximately 14-18 million clinical malaria cases are reported by public health services each year (MOH, 2005)

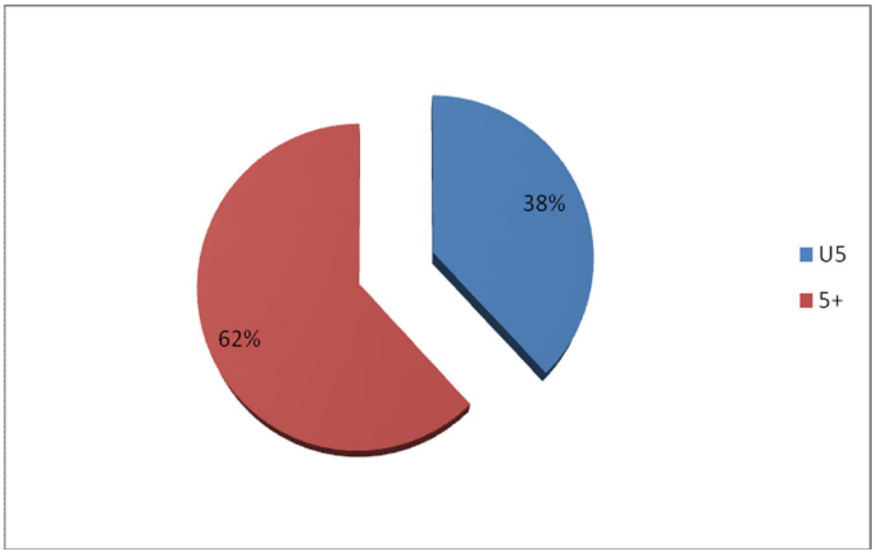

Figure 3. Total death below 5 years old and 5 years and above caused by malaria disease. Year 2006.

The percentage of death among children under 5years of age in Figure 3, is totally out of proportion with the percentage of the very young in the total population, moreover, given that most children lack the immunity that previously infected adults have (Connor *et al*, 2006).

The population of the United Republic of Tanzania constitutes the largest number of persons at risk for malaria among all 15 Presidents Malaria initiatives (PMI, 2005) countries: approximately 36.7 million individuals of which 35.6 inhabitants are in the mainland 93% of the population is at risk in the mainland and 1.1 million in Zanzibar where 100% of the population is at risk (PMI, 2005). An estimated 100,000 inhabitants malaria deaths occur annually in Tanzania (PMI, 2005) of which an estimated 80% are children under five years of age, according to (MOH, 2006) 38% of children under 5 years old died of malaria (Figure 3). The disease is responsible for more than half of deaths among children under five years of age in health facilities and up to one-fifth of deaths among pregnant women (Malaria Operational Plan-TANZANIA, 2007). According to (MOH, 2008) the number of morbidity and mortality among outpatient and inpatient admissions accounts for up to 40 percent.

Fifteen Presidents Malaria Initiatives (PMI) countries was launched in June 2005, by George Bush; (former President of United States of America) in order to fight against malaria and Tanzania was among of those 15 countries.

Statistics for other East African countries show that in Uganda in year 2002 and year 2003 malaria case were 5,694,342 and 7,147,152 resulting in 6,735 and 8,500 deaths, respectively while in Kenya, 40,000 infant deaths are attributed to malaria every year (AIACC Working Paper, 2006).Thus, in the East African countries, this disease is ranked as the first cause of morbidity and mortality in both children and adults.

1.2 Objectives of study.

The objectives of this thesis are the following:

1. To determine spatial data distribution of malaria using spatial analysis tools and GIS software, and the generation of cartography which will show the most affected regions by malaria and related factors which influence malaria epidemic in Tanzania

2. To determine the regions which are at high risk of contracting malaria.

3. To come up with detected variables which contribute most to malaria epidemic in each particular region within a country.

4. To come up with information which will be used by local government authorities in order to take the best course of actions in designing and monitoring interventions programmes in order to control and suffice the malaria epidemic within a country at large.

1.3 Research questions and Project goals

The aim of this work is focused on finding solutions of following questions which are;

1. Which are the most affected regions and where are they located?

2. How can the results be integrated in Tanzania Spatial Data Infrastructure?

3. How can the results be used for planning and management control of malaria in Tanzania?

1.4 Thesis structure

There are five chapters in the thesis. Chapter one introduces the thesis in general including the objectives of the thesis, research questions pertaining to the topic and the challenges to eliminate malaria transmission in Tanzania followed by description of other four chapters as stipulated below:

Chapter two describe the impact of Malaria to the National Economic perspective in Tanzania and various actions and strategies which have already taken by the Government of the United Republic of Tanzania and Sub-Saharan countries in fighting against Malaria epidemic.

Chapter three gives comprehensive methodology used to obtain the results, the importance of Geographic information systems and to the same, is used to generate various malaria maps and graphics for analysis. In the other hand, statistical data analysis are performed with consistent and established set of tools to analyze spatial datasets and modeling by means of open source software "R".

In the aspect of chapter four this is the heart of the matter specifically the indicators and various variables used in this work are introduced. Spatial distribution and Graphics to the analysis and results are realized. Discussions and suggestions are given as well in this chapter.

Finally chapter five draw up a conclusion and recommendations based on the vector risk variables which contribute most to malaria epidemic in Tanzania.

1.5 Challenges of elimination of malaria transmission in Tanzania

Personal behaviour using mosquito bed nets to reduce malaria intensity through mosquito bite are very low. This is due to the fact that some people complain of discomfort once they sleep under mosquito bed nets in this regards, it becomes complicated to draw a mechanism or any rules which may control and reinforce individual, family and groups especially in the collective households that they must use mosquito bed nets during night while sleeping. Mosquito bed nets reduce malaria transmission through mosquito bite.

There is a concern that many people cannot afford to buy mosquito nets for the entire household. On average, each household of six or seven persons had 1.5 bed nets, and only about 2.4 persons per household use bed nets. This signify that, on average, four persons per household do not have access to bed nets and may be subject to mosquito bites, with the consequent malaria disease potential (Yanda *et al*., 2005). On the other hand, the quality of mosquito nets differs some have high qualities and are very expensive and live longer than those with low qualities. Most of people especially in rural areas opt for mosquito bed net with low quality because they can afford to buy them if available. Usually bed net with low quality get worn or damaged easily and allow the mosquito to enter through small holes. The possibility of new replacement is in vain due to difficulties caused by poverty.

Environmental impact while applying insecticide in order to destroy favourable mosquito breeding areas especially the areas with rich of ecosystems in natural features like rivers, pond and flood plains some of the insect dies in this operations while other organism depend on these insect for the life cycle. For example applying *Lambda Cyhalothrin* during IRS as recommended by (WHO, 2005) other study has shown that this insecticide has highly toxic to fish as well to bees (NPTN, 2001).

Introduction to vaccinations which still ongoing various efforts have been laid down to find malaria vaccine this would be a solution of fighting against malaria not only in Tanzania but globally mostly Sub-Saharan African countries.

One of the achievements of this work is that gained information is shared with other data stakeholders in Tanzania in order to fulfil the SDI initiative requirements. The current situation shows that most of the institutions have limited use of spatial data with old technologies and most of data are in analogue and out of date, few are in digital format with no link to current data sharing requirements. In addition to this, there is no sustainable established mechanism for regular data updates and also fewer specialists in handling geographic information. Spatial data and SDI initiatives have potential applications to improve the current situation in fighting against malaria epidemic in Tanzania.

2. IMPACT OF MALARIA TO THE NATIONAL ECONOMY OF TANZANIA

2.1 Introduction

As mentioned earlier Malaria remains a major public health problem in sub-Saharan Africa. The disease continues to be a cause of illness and death in Tanzania and African countries (WHO, 2008). There is significant correlation between malaria and poverty. Countries with intensive malaria have income level of 33 percent compared to those without malaria (Gallup and Sachs, 2001). The countries which have reduced Malaria in the past half century in last 5 years after elimination of the epidemic their economic growth has been substantially higher than growth in neighbor countries with malaria. The impact of retarding the economic growth caused by malaria are related to among other factors initial poverty, economic-policy, tropical location and life expectancy. In comparison with other diseases malaria has shown a great negative impact on the economic growth of the countries (Gallup and Sachs, 2001).

2.2 Situation in Tanzania specifically

Particularly in Tanzania, malaria turns to ravage the population and the economy in almost every sector. For instance; in the education sector, students and pupils attacked by malaria take absence from classes and this has a negative impact on the academic performance. The disease weakens the labour force of the country causing low productivity and in turn aggravates the poverty situation. For instance, employed persons take absence from work if attacked by malaria. In very severe case, attacks may lead to death if not diagnosed early and a proper treatment administered. The situation is even worsened by the abject poverty that prevails in the country.

In addition, the death of young generation, both male and female “man power” affects the growth of the national economy in many areas, the development of institutional capacity which requires skilled workers and leaders, professionals in various areas such as, medical cares, education, agriculture, surveyors and engineers just to mention a few cannot be easily replaced once they have died.

2.3 Fighting against Malaria

Various actions and strategies have been initiated by the Government of the United Republic of Tanzania in order to control and prevent malaria. Considerable amounts of its limited health budget each financial year are allocated to address malaria and malaria related disabilities. Household expenditure related to the epidemic is high and mainly spent on the malaria treatment.

Most drugs used previously for the treatment of malaria have apparently become less efficient to the disease causing *Plasmodium* which seems to have developed resistance to the drug because of this, the government has decided to introduce the

Artemisin-based Combination Therapy (ACT) (MOH, 2008) which is a response to the emerging resistance of malaria parasites to mono-therapy using antimalarial drugs like *Sulphadoxine Pyrimethamine (SP)* in this due, it is expected the cost will rise enormously.

Another effort in this fight is The Abuja declaration whereby the country was represented by Benjamin Mkapa, the former president of Tanzania on concerted effort to reduce the occurrence of malaria within the continent and agreed that, by 2010 the death caused by malaria should be reduced by 50%. Observed data at this time shows that the current situation is not to the success as expected due to various difficulties within individual countries. In Tanzania the country has laid down policy on malaria with the long term goal initiatives in order to control malaria and reduce morbidity and mortality of malaria transmission, and special attention is being directed to the most vulnerable groups, children under 5 years of age, pregnant women, and the poor people in order to promote economic development.

2.4 National Policy on Malaria

The disease remains a major impediment to socio-economic growth and welfare. To reduce the occurring of malaria, the Government of Tanzania through the Malaria Control Programmes, the National Malaria Control Programme (NMCP), and the Zanzibar Malaria Control Programme (ZMCP), has undertaken various actions supported by development partners such as the Global Fund to fight against Malaria (GFATM), the US President's Malaria Initiative "PMI", The World Bank, and United Nations Children's Fund (UNICEF).

The goal of the National Malaria Medium Term Strategic Plan (NMMTSP) 2008–2013 is to reduce the occurrence of malaria in the country by 80 percent. This goal is in line with the Global initiative, that advocates a rapid scaling of interventions to achieve the roll back malaria target of universal coverage of 80 percent by 2010 and the Millennium Development Goals by 2015.

The main objective of the Zanzibar Malaria Medium Term Strategic Plan 2008-2012 is to further reduce the burden of malaria by 70 percent from the 2006 level of 35 percent to 11 percent by 2012. This goal will be achieved by maintaining high coverage of effective interventions and establishing epidemic detection and response mechanisms.

The vision of the malaria medium term strategic plan is for Tanzania to become a society where malaria is no longer a threat to the health of her citizens, regardless of gender, religion or socio-economic status.

The recommended key malaria control strategies include:

- Improve early recognition of malaria and prompt treatment with effective antimalarial drugs;
- Prevent and control malaria in pregnancy, by increasing coverage with at least two doses of Intermittent Preventive Treatment (IPT) among pregnant

women attending public health services, and by promoting the regular and correct use of long-lasting insecticide-treated net (LLIN);

- Prevent infection with malaria by maintaining high coverage of LLITNs, with specific emphasis on vulnerable groups, complemented by other vector-control methods such as indoor residual spraying;
- Strengthen the Ministry of Health and Social Welfare (MOH, 2006) and key stakeholders support for malaria control through improved planning, management, partnership, and coordination; and
- Strengthen monitoring and evaluation surveillance system to support localized control and enable early detection and response to malaria epidemics.

Concerted effort, effective partnership, and coordination of all key players in malaria control at all levels are critical to achievement of control and elimination of malaria in Tanzania.

2.5 National Strategy for Poverty Eradication (MKUKUTA)

Malaria is among the development agenda in the National Strategy for Poverty Eradication (MKUKUTA), and the National development Vision for 2025. The development of the National Guideline on the Prevention and control of malaria within the country is an achievement of the Government that shows its commitment to fight the epidemic and to improve the well-being of the people.

It is expected from this work that spatial information attached with analyzed attribute statistics pertaining to malaria epidemic is vital for supporting correct decision with regards to fight against Malaria within a country and fulfilling MKUKUTA objectives in suppressing the epidemic in Tanzania, one of these objective is that by 2015 half of all districts in Tanzania mainland must be covered with indoor spraying against malaria.

In addition to that, various extracted multiscale maps and graphics showing the most affected areas and associated indicators which are favorable to mosquito densities through analyzed data is a vital to this process.

Moreover, lack of current data for example smallest spatial unit at the village level, which was suppose to be used in this work in steady region boundaries are used however, available dot map which represents the villages are derived from the topographic maps and most of them are old and out of date as were produced in 1960s and early 1970s if this dataset is used cannot show the current situation since there are new born villages and other villages are no long exist so to use this data might lead the mis-represent the current spatial distribution once the current dataset is used.

Lack of location data for the household's living close to the areas which seem to favour mosquito breeding, this data was important for spatial analysis in buffering from the household towards mosquitoes breeding areas. The result after buffering operation might have shown the proximity from both the household premises and targeted mosquito breeding areas.

Also lack of rainfall and temperature data which usually shows the changes in suitability for transmission of the disease caused by natural situation such as climate anomalies in regions where the environment does not allow sufficient mosquito and parasite are important in providing the information in monitoring the conditions that are likely to give rise to the malaria epidemic (Connor *et al,* 2006). For example climate anomalies are often periodic and temporary, and there is often a return to the original unstable state. Examples include the epidemics occurring in the semi-arid areas of Southern Africa in 1996-1997, East Africa in 1997-1998 El Niño. During this period there were more diseases erupted in Tanzania in many areas especially malaria disease caused by flood plains, water steams etc (Figure 4). El Niño events lead to elevated temperatures and enhanced precipitation, which results in increase malaria transmission (Lindblade *et al*, 2000).

Figure 4. Flood plains after heavy rain full contribute most to malaria epidemic

Lack of suitable data on elevation dataset at minimum interval 30-90m, the current available constitute interval of 308.2m of which is not suitable in 3D analysis which allow to capture valley which seems to be habitat for mosquitoes (Hetzel *et al*, 2007)

Malaria poses no risk to inhabitants of a place above an altitude of 2000m (Ethiopia, 2005). Since in this work already a shapefile of Region boundary attached with various statistical data is achieved it is recommended that in future once unavailable data is in place, further study must be undertaken using the same frame so that the analysis can be done based on smallest spatial unit with the size of 80-100 households coverage (Tanzania-National Bureau of Statistics, 2012). It is thus critical to know which variables are mostly contribute to malaria disease in each particular region, equally it is important to come up with a designed mechanism in order to control and prevent malaria transmission in Tanzania.

3 DATA AND METHODS

3.1 Introduction

In this study geographic information system technology are deployed since it has emerged as the core of the geospatial technologies and has shown a big capability in integrating wide range of various dataset available from different sources including photogrammetric, remote sensing, global positioning system (GPS), aerial photography popular known as ortho-photo maps and other archived data for example cadastre and other related datasets. In this work GIS is grouped into four modules according to the structured malaria epidemiology as follows:

- Spatial distribution of the phenomena
- Mapping
- Geo-processing tools
- Geo-statistical analysis

All processes are fully described and illustrated with graphics as per the derived results in chapter four. The contributions of GIS tools in better understanding of data on malaria transmission process are higher and valuable contribution in this work. The outcome is the information which is vital in decision making in monitoring and controlling the malaria epidemic in Tanzania and the policy formulation and improvement.

The GIS tool is used based on analyzed non spatial data collected through a survey undertaken in Tanzania (HIV/AIDS and Malaria Indicators, 2008). Since malaria risk areas are geographic specific, population risk are geographic specific as well in this regards, GIS is used in this work in order to gather, integrate and manipulate the data where the geographic location at a region level is important or critical to the analysis. Moreover, what is true is the capability of incorporating large sets of data and various graphics which are generated for analysis and discussion.

Additional to this, statistical package open source software ‘R’ is used in analysis and data modeling. In other hand this package is used since it is strong in reducing large number of variables based on their homogeneous of which other software cannot achieve (seventeen variables are used in this work). Principal component values are calculated and new principle components values related to malaria cases are calculated as well in order to determine a variable which contribute mostly to malaria epidemic in each particular region.

The considerable future of development of GIS technology is parallel with the utilization of geo-statistical tools which has shown high capability to provide new insight into malaria epidemic and the complexity of its transmission potential in endemic areas (PubMed, indexed for MEDLINE).

3.2 Data

Two types of official datasets were received from Tanzania namely, (Tanzania HIV/AIDS and Malaria Indicator Survey year, 2008) from National Bureau of Statistics and Total number of deaths caused by Malaria epidemic (Tanzania Ministry of Health, 2006).

Data collection was done from October to March covering the entire country Tanzania mainland and Zanzibar which is part of Tanzania and constitutes two Islands, Unguja and Pemba. During the Survey, 26 regions and 153 Districts were covered that make up the national territory. A total of 17,670 adults whose age ranged from 15-49 + were interviewed during a survey and the country composed of total populations of 34,190,168 (NBS-Population and Housing Census, 2002)

3.3 Methods

District boundaries were dissolved to Region boundaries in order to carry out spatial analysis by regions (Figure 5). Seventeen variables were chosen from a total of 37 variables, and were selected manually and compiled together in a single table. The original dataset were compiled at district level but in this study the focus is at region level therefore the dataset again were gathered to the region level by means “R” software.

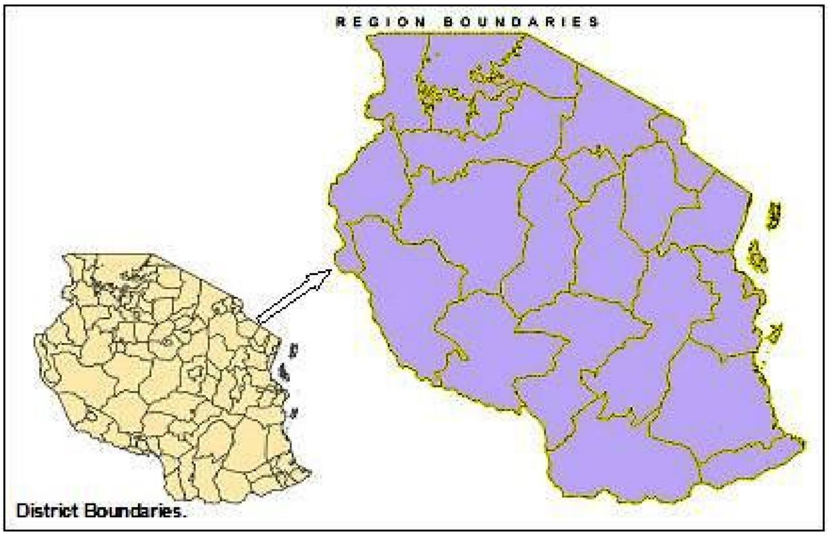

Figure 5. District and Regional Administrative units of Tanzania.

3.3.1 Descriptions of used variables

Detailed descriptions, graphics, analysis and suggestion based on each variable are taken care in chapter four, for now this is overview of them:

1. Malaria cases abbreviated as **(MAL_CASE)**, it shows the impact of malaria disease within the country by region. Malaria cases defer in several respect for instance, malaria transmission defer from one area to another, one person to another, from one group to another. The spatial distribution based on this variable is carried out in order to determine the region with high occurrence of malaria epidemic.

2. **Number of persons without bed net for sleeping (Hbfs0),** it shows the number of persons who do not own mosquito nets. In this study, the spatial distribution of this variable is performed in order to cover the essence of persons without bed nets for sleeping. This information gives the outlook whether a variable cover a large scale or small scale for persons owning the mosquito net.

3. Number of persons with bed net for sleeping (Hbfs1), this provide information about how many mosquito nets the household possesses. It is assumed that the more the coverage of mosquito nets lower the mosquito bite intensity visa and visa- versa the less the coverage the more the intensity of mosquito bite and increasing malaria transmission. Mosquito bite intensity is inversely proportional to number of mosquito bed nets.

This variable can be expressed by simple mathematical model as,

$$\Phi = \frac{1}{\rho}$$

Where Φ= Mosquito bite intensity

1= Number which can be multiplied by number of population

ρ= Number of nets

4. **Number of households did not spray against malaria over last 12 months (Hsamil12m0)**. One of the ways of reducing mosquito densities is applying indoor residual spraying. Analyzing this variable gives information on the scale of indoor residual spraying which has given to attention in fight against malaria transmission.

5. Number of household's living close to a river or stream (SW42), this represents permanent natural water bodies which contribute to malaria transmission as favourable areas for mosquito breeding.

6. Number of household's living close to the ponds, flood plain and lake (SW43), this is similar to SW42, the difference between them is geographic location within a region. Even though the contribution to malaria disease is the same but the mode of fighting against the disease through these variables differ from one region to the other, some regions have many rivers but without flood plain and visa verse.

7. Number of households who uses bush/ field as Toilet facility (TF41), this is an indicator about the conditions the people are living, according to poverty (housing condition) it shows how a household without toilet facilities in steady they use bush field as toilet facilities. Mosquito breeding prefer dissolved organic matters, in this work this variable is counted as one of mosquito vector among other selected variables.

8. Number of household's using traditional pit latrines (TF22), Pit latrines are used in most of the habitats in Tanzania as a source of toilet facilities and it is one of the vector risk variables to malaria epidemic (Kirby *et al*, 2008).

9. Number of households living close to open well into yards or plots and public open well (SW22, SW23), one of the major problem faced by most of Tanzanians is source of water. Constructions of water wells are given to high priority and continue to be planned in order to save human needs such as drinking water, energy generation, and agricultural production. Despite of the merits it has shown that open wells are leading to shifts in vector mosquito populations.

10. Number of household using insecticide treated bed net for sleeping (Psuetb1), the use of insecticide bed net is a major goal of malaria control initiatives, but in Tanzania remains low because of the cost and logistics. The information which shows the coverage of household's uses insecticide bed net is important as it gives the significance of malaria transmission in the country through mosquito bite.

11. Number of households sprayed against malaria in 12 months (Hsamli121), to spray against malaria is one of the primary vector control interventions for reducing and interrupting malaria transmission if well implemented.

12. Number of Households who does not use insecticide treated bed net for sleeping (Psuetb0), in some of the area in the country is very hot it was observed that some of people especially adults are not using bed net because of uncomfortable while slept this might cause adult to transmit malaria to children's since once infected mosquito bite children's.

13. Number of households living close to neighbor having open well (SW24). Open wells are a malaria transmission vector since they are favouring mosquito breeding.

14. Number of household's living with piped within the Yard or Plots (SW12), piped is used as a source of water normally is categorized and grouped similarly to latrines, garden within a plot or yard and if it is not well treated might become a place which produces mosquitoes breeding, specially watershed surrounding the pipe into the yard when waste water takes long dug in the dirt, and they quickly become muddy and clogged with waste and the area become wet throughout and pools of water and waste form in the surrounding once they are clogged, and this is where mosquitoes lay their eggs.

15. Number of households living close to piped into dwelling (SW11), looks to be similar from (SW12) variable the only difference is that this saves more number of household compared to (SW12) and the impact of malaria transmission caused by (SW11) is larger compared to (SW12) because saves many people at a time which contribute too much water waste around the surrounding and the impact of increasing mosquito density is larger.

16. Number of households using poor/flush toilets (TF11), this affect mostly the people who are living in the urban areas especially in the cities. The variable contribute to malaria transmission once the toilet does not functioning properly especially when septic tank has leakage and water thrives in the surrounding at this state mosquito lay their eggs and multiply enormously.

17. Number of households living close to natural spring water (SW41), usually natural spring water is used as a source of water in Tanzania, the surroundings is always covered with bushes, grasses and water by itself. Such an environment leads to shift in vector mosquito population.

3.3.2 Working with R software

The software "R" is open source software for spatial data analysis. The data defined above is saved in table attached to R software and each region is given a new code while working with R and at the end of each session each new dataset are extracted with respect to each region until all 26 regions are accomplished with all 17 variables. The dataset belonging to each region is aggregated into each particular region. After having all table with necessary information required this individual table representing each region are joined together in order to have one common table and later the file is used in JOIN operation in ArcGIS with a generated a shapefile at region mapping unit as can be depicted from (Figure 6).

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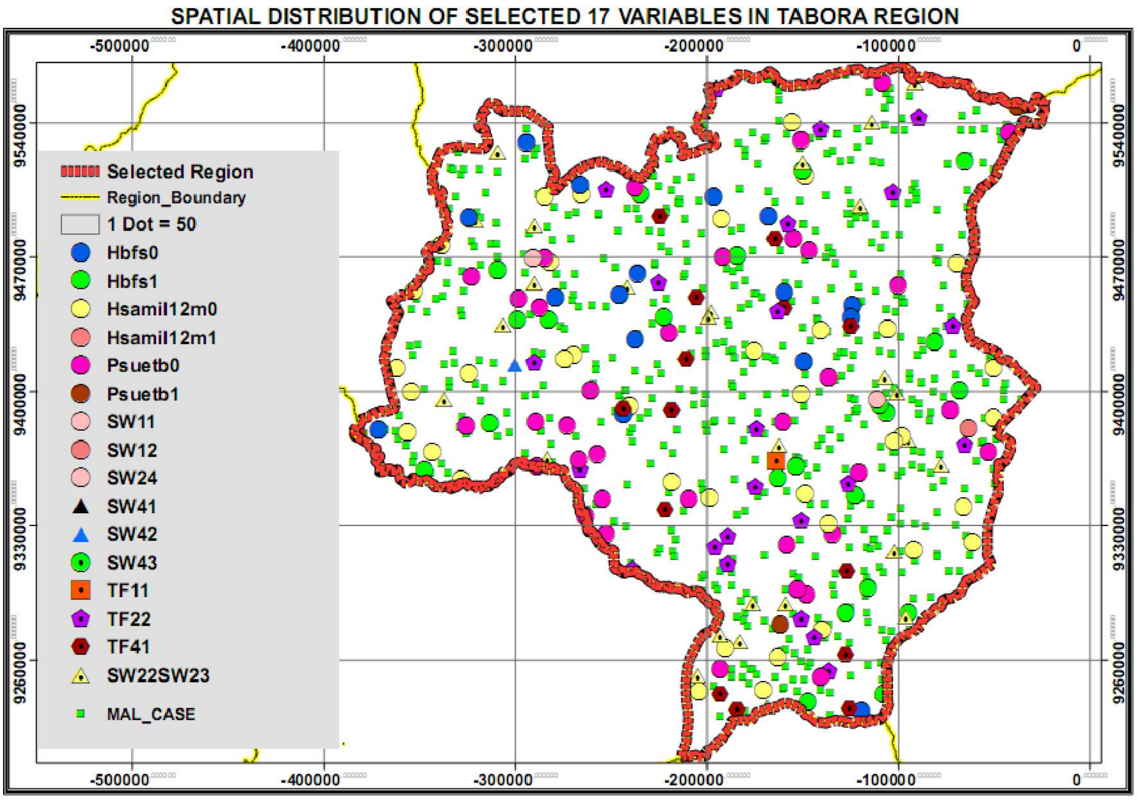

Figure 6. Spatial distribution of all seventeen variables in Tabora region. Year 2008.

3.3.3 Working in ArcGIS

In this work regions are regarded as smallest mapping unit whereby the data are distributed spatially. A shapefile with ward boundaries which is smaller mapping unit is dissolved to lager level “Regions” and shapefile with region boundaries are extracted in ArcMap (Figure 5). Small silver polygons contained into some of the polygons after dissolving process are cleaned by deleting them so that can not appear as islands. New shapefile with region boundaries is saved as a project so that join and other operation can be done at this stage.

3.3.4 Join operation

Shapefile attributes and statistics attributes are joining together in ArcMap in order to extract various maps for spatial analysis and discussions based on the obtained results. Text (Tab delimited, *.txt) format is introduced to statistics data in order to make join operation a success.

3.3.5 Malaria maps generation

When the described process is complete, various maps showing spatial distribution of various variables at a region level are created, and at this stage preliminary analysis is realized. This is a preliminary analysis because further analysis through “R” especially principal component analysis is later performed in order to validate the results obtain from the maps generated by ArcMap.

3.3.6 Overlaying

From (Figure 6) is illustrating the spatial distribution of all seventeen variables, the variable which contribute mostly in this region cannot easily be recognized that’s why overlaying operations are carried out in ArcMap, and is essential as two variables with similarities are overlaid together in the same layout in order to determine which variable contribute mostly to malaria epidemic. Dot density map is extracted and displayed for analysis. In the overlaying operation, dot size are fixed throughout the operations and dot value varies in accordance to how larger the values of variables are, and the values are fixed the same throughout in the almost of all variables.

It very important to note that: the dots which are distributed into maps is not spatial data (X, Y) coordinates, these dots are generated by a software automatically in steady of color map “thematic map” therefore if appears that the higher concentration of the dots in certain area within a region does not signify that it is a place where the incidence are mostly occurring in that area within a region in steady should be considered as the representation of the entire region.

3.3.7 Principal component analysis (PCA)

In general, each variable contribute to malaria epidemic independently and one variable can contribute not equally from one region to the other. To determine the most contributing variable the process PCA is subsequently deployed and a code used to generate the values is established and used (**ANNEX A).** The results from this operation are illustrated in Table 1.

New principle components values related to malaria cases are calculated by using principle component values obtained from (PCA). The equations are formulated based on seventeen variables ready for calculation (**ANNEX B).**

Coefficient matrix

components	**Standard deviation**	**Proportion of Variance**	**Cumulative Proportion**
Comp.1	2.5756848 1	0.4146345 0	0.4146345 0
Comp.2	1.7357583	0.1883036	0.6029381
Comp.3	1.4625175	0.1336848	0.7366229
Comp.4	1.19844918	0.08976753	0.82639044
Comp.5	0.82991212	0.04304713	0.86943758
Comp.6	0.74913412	0.03507512	0.90451270
Comp.7	0.74160850	0.03437395	0.93888665
Comp.8	0.53509629	0.01789550	0.95678215
Comp.9	0.48029943	0.01441797	0.97120012
Comp.10	0.42746968	0.01142065	0.98262077
Comp.11	0.318640329	0.006345729	0.988966495
Comp.12	0.280475426	0.004916654	0.993883149
Comp.13	0.24721392	0.00381967	0.99770282
Comp.14	0.165819367	0.001718504	0.999421323
Comp.15	0.085632514	0.000458308	0.999879631
Comp.16	0.0438851549	0.0001203692	1.0000000000

Table 1. Coefficient matrix from principle component

3.3.8 Regression

The regression technique is carried out by developing a code see **ANNEX C** which are used in calculating new values showing individual contribution to malaria epidemic. All seventeen variables are considered at this stage.

Furthermore, equations are formed in order to calculate new score values in the regression operations by using calculated four important “principal component” related to malaria cases. The results are shown on Table 2.

4 RESULTS AND DISCUSSIONS

4.1 Introduction

Four main indicators are considered in this work which is in turn associated to seventeen variables in order cover a wide range which was not covered previously. Spatial distribution of the information of the most affected areas from malaria epidemic and areas favourable to mosquito breeding are identified and shown from generated malaria maps of which the analysis is carried out at this stage. Results and discussion based on both Principal components and maps generated by ArcMap showing the behaviour of the data are realized as well and suggestions focus to the analysis are also provided.

Gained information from this chapter will be used by decision makers and other stakeholders to find a best way of improving, planning and developing a mechanism in designing and monitoring interventions programmes in order to control and preventing malaria disease in Tanzania.

Four Indicators resulting from analysis are:

- Ownership of mosquito nets
- Use of mosquito nets,
- Indoor residual spraying
- Number of persons slept under an insecticide bed net.

In conjunction to the indicator above housing conditions are considered in order to provide the information based on two indicators which contribute to malaria transmission as they are most favourable to mosquitoes breeding.

These two indicators are;

- Water Facilities
- Toilet Facilities

4.2 Mapping of Malaria cases in Tanzania.

Total deaths caused by malaria disease are mapped and portrayed spatially to validate the analysis and results provided after the spatial distribution of all selected malaria transmission variables performed.

Figure 7 shows the spatial distribution of malaria cases of patients before testing of malaria (*BS ve+*) as reported from various Health Facilities in year 2006 while (Figure 8) shows Total tested and found with Malaria *Plasmodium,* total deaths of persons below 5 years old and 5 years and above.

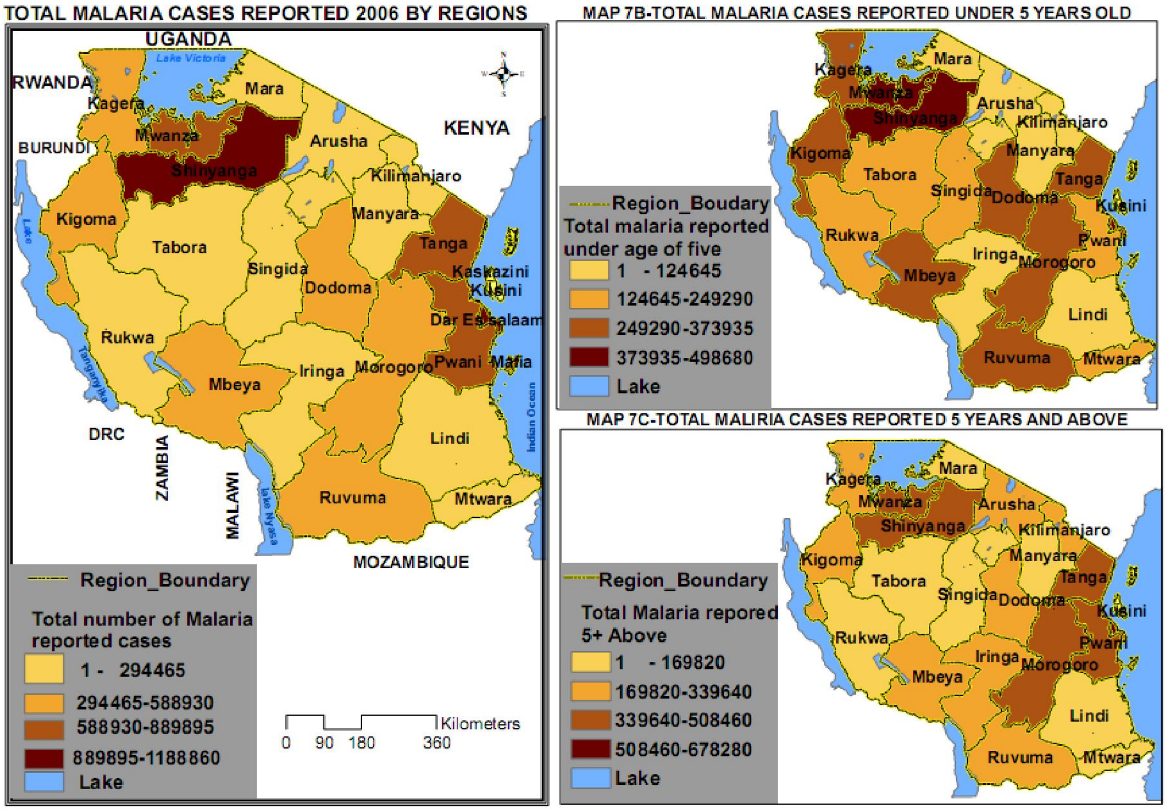

Figure 7. **(A)** Total reported malaria cases, Map **(B)** is for children below 5years old and Map **(C)** is for persons with more than 5 years old. Year 2006.

Dar Es Salam and Shinyanga regions are leading with higher total number of malaria cases within a country followed closely by Tanga and Pwani regions. (Figure 7 B) and **(**Figure 7 B) are representing spatial distribution of malaria cases for the children under 5 years old and 5 years and above respectively. Based on children under 5 years old, Dar Es Salaam, Shinyanga and Mwanza regions have higher malaria case for the children under 5 years old followed closely by Kagera, Kigoma, Mbeya and Dodoma, Morogoro, Ruvuma and Tanga regions.

Spatial distribution show that almost each region has more malaria cases among children under 5 years of age while malaria cases for persons with age from 5 years and above Dar Es Salaam region shows to constitute highest number of casualties as reported with malaria cases.

However, in the same health facilities total number of persons reported with malaria cases was tested with (*BS ve+*) in order to determine persons with malaria positive. A person with malaria parasite is not necessary to die from the disease but once it is too late to the person to attend to the hospital it causes malaria severe which there after causes a death to a person (Figure 8 A).

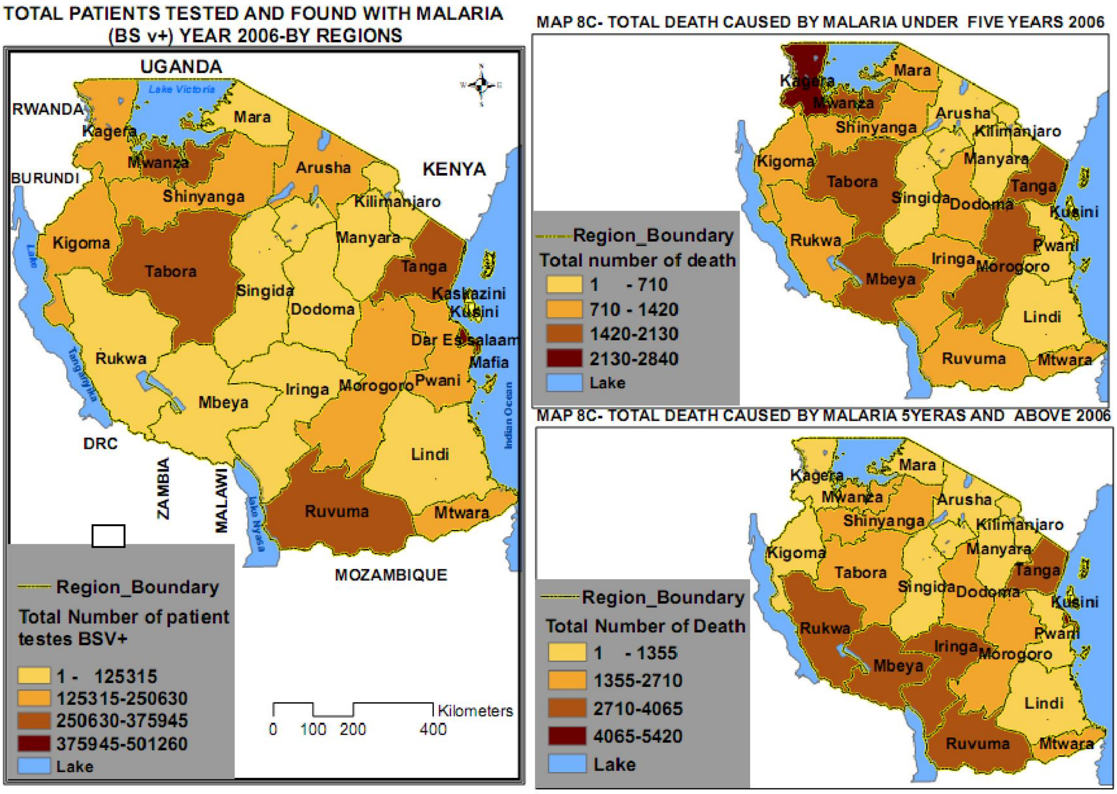

Figure 8. **(A).** Total persons with malaria (*BS* ve+), Map **(B)** Total death below 5 years old and Map **(C)** Total deaths 5 years and above by region. Year 2006.

Dar Es Salaam region has shown with highest number of persons tested and found with malaria plasmodium (Figure 8 A) compared to other regions and is followed closely by Tanga, Ruvuma, Tabora and Mwanza regions with persons affected by malaria. Kagera regions constitute the highest number of death of children below the age of 5 years (Figure 8 B), followed by Tabora, Mwanza, Mbeya, Tanga and Morogoro regions while Rukwa, Mbeya, and Dare Es Salaam, Ruvuma and Tanga regions have higher number of death of persons with the age of 5 years and above (Figure 8 C).

Dar es Salaam which leads with highest total number of persons reported with malaria cases and highest number of persons with malaria plasmodium constitutes lower number of death of children below the age of 5 years (Figure 8 B).

4.3 Households owned mosquito nets.

This indicator determines the coverage of mosquito net in the country. The lower the coverage of mosquito nets in the household, allow more rapid spread of malaria intensity. The considered variables are; **Number of persons without bed net for sleeping** and **Number of persons with bed net for sleeping** however, this work does not touch on means of availability of mosquito net from place to place due to unavailable data which can be used to extract such information.

The availability of mosquito nets differs from one place to another and might be possible in urban areas and difficult in rural areas. Further investigation must be carried out in order to come with the information based on difficulties which are faced by individual household in acquiring the mosquito nets. This will allow the government to develop a mechanism of easy access to mosquito nets in some of the places where the means of getting mosquito net is not well rationalized.

Figure 9. George W. Bush (former president of USA) under mosquito net was mobilizing use of mosquito net in the fight against the malaria in Tanzania.

4.3.1 Number of persons without bed net for sleeping (Hbfs0)

Spatial distribution is performed based on the variable mentioned above and the analysis was done and the result shows that most of households within the regions in Tanzania mainland don’t own mosquito nets for sleeping (Figure 10). Moreover, Iringa and Manyara regions have ranked the highest with about 72% of households of total population does not own mosquito nets for sleeping and there are malaria cases in these regions (Figure 7 B).

In some regions like Dar Es Salaam about 34% of households of the total population does not own mosquito nets for sleeping followed by Mwanza and Mara regions. Dar Es Salaam is the ranked highest with total death of person with age of 5 years old and above caused by malaria disease as well as Mwanza region (Figure 8 C).

In Tanzania Zanzibar is about up to 17% of households of total population who do not own mosquito nets for sleeping. In comparison between Tanzania mainland and Zanzibar, it shows that Zanzibar has fewer households who do not own mosquito nets for sleeping (Figure 10).

TOTAL NUMBER OF PERSONS WITHOUT BED NET FOR SLEEPING - BY REGIONS

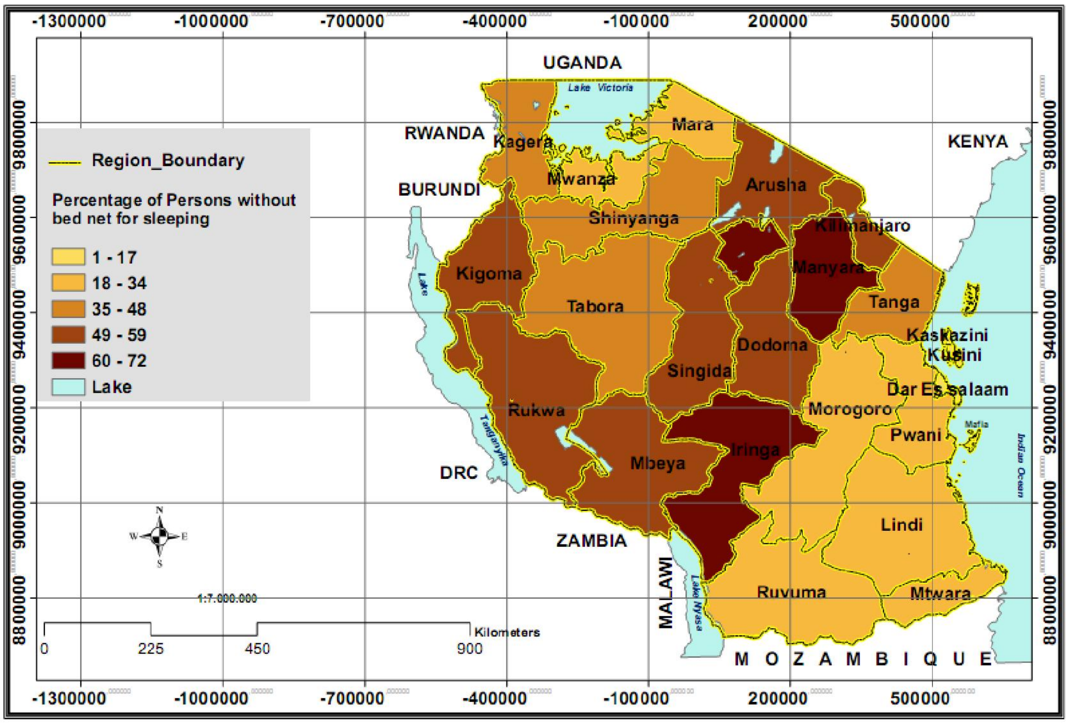

Figure 10. Spatial distribution of persons without bed net for sleeping. Year 2008.

TOTAL NUMBER OF POPULATION 2002-BY REGIONS

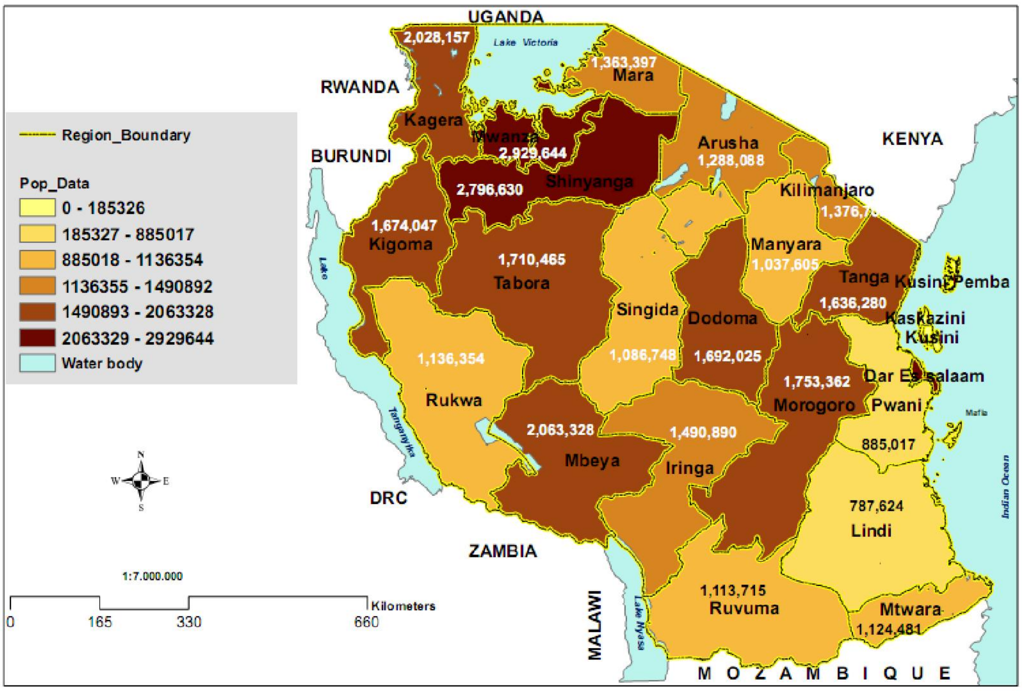

Figure 11. Spatial distribution of total population by regions. Year 2008.

The spatial distribution of population by region can be depicted from (figure 11) whereby the highest populated region is Mwanza, followed by Shinyanga and Dar Es Salaam malaria cases are very high in these regions as well.

According to the publication (Tanzania HIV/AIDS and Malaria Indicator, 2008) the Government of Zanzibar decided to subsidize the cost of buying mosquito nets and this motivated local to buy mosquito nets. Secondly, also the entire coverage of the Island with the population being 40 times less than that of Tanzania Mainland, it was possible for the government to subsidize the cost of buying mosquito nets in Zanzibar rather than in Tanzania Mainland. Thirdly the terrain of Zanzibar is not much complicated as the rest of the place are easily accessible compared to Tanzania mainland where the logistics is very complicated in some of the places to reach.

4.3.2 Number of persons with bed net for sleeping (Hbfs1)

This variable was considered in order to determine the regions having higher number of persons who owns bed net for sleeping, and further analysis was done based on both two variables in the regions in order to determine one variable from the other which contributes mostly to malaria epidemic in each particular region.

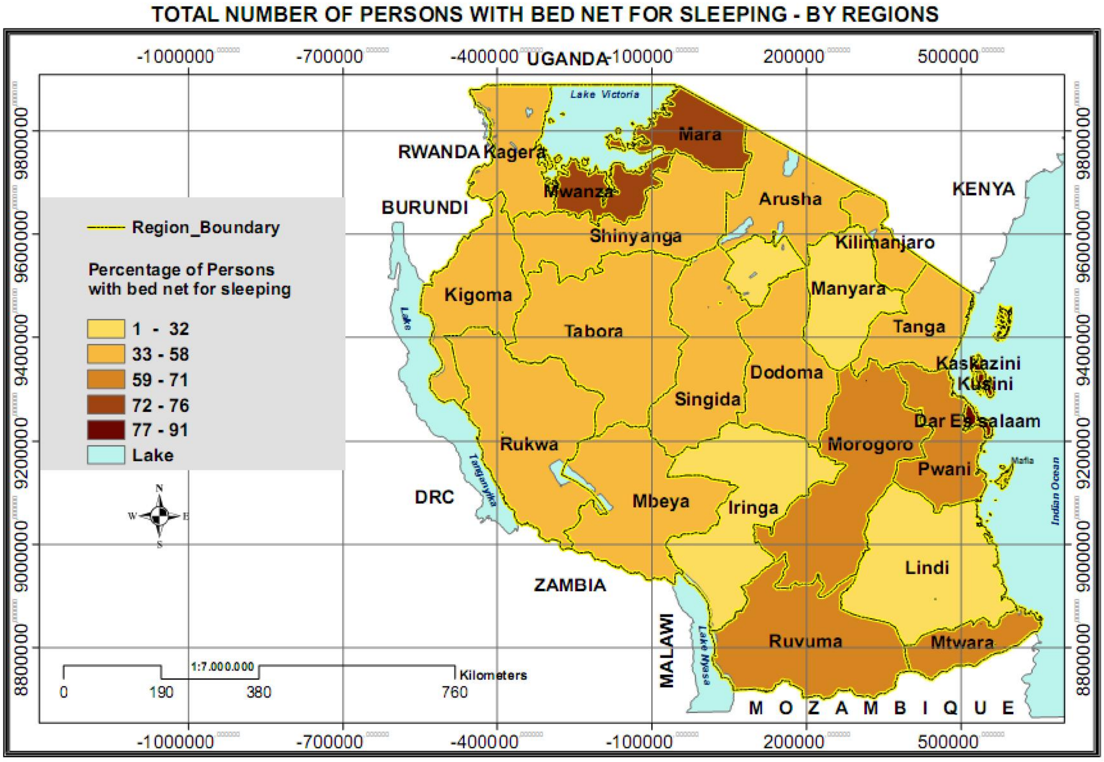

Figure 12. Spatial distribution of persons with bet nets for sleeping. Year 2008.

Even though the distribution coverage of mosquito nets in Tanzania mainland seems to be low but still some regions some of the households have made a great effort to own at list one mosquito net for sleeping (Figure 12). For instance in Dar Es Salaam region about 60% of households of total population (Figure 11) own mosquito net for sleeping. This is relatively high compared to other regions in Tanzania mainland. However, still in this region though with high number of households with bed nets, malaria cases are still high with highest number of deaths among person aged 5 years and above. Simultaneously low number of deaths among children's below the age of

5 years. This signifies that more children's uses mosquito bed nets for sleeping compared to adults.

Mwanza and Mara regions rank the second with a high number of persons with bed nets and Mwanza is among of regions with high malaria cases while Mara region has moderate malaria cases. The rest of the regions have shown low pace of owning mosquito nets for sleeping. Iringa region shows the lowest number of households who owns mosquito bed nets for sleeping and malaria cases are still high in this region as well.

In Zanzibar most of the regions owns mosquito bed nets. For example Mjini Magharibi region more than 72% of households of total population are owning at list one bed net for sleeping and in other regions the results shows that in Zanzibar there are more number of households owning the mosquito bed nets for sleeping compared to Tanzania mainland.

Spatial distribution is performed and the results shows that the variable households with bed for sleeping dominates mostly in all of the regions in Zanzibar (Figure 13) while the variable households without bed net for sleeping dominates in almost many regions in Tanzania mainland except Dar Es Salaam and Mara regions (Figure 14). This means that the variable households without bed nets for sleeping contribute mostly to malaria transmission in Tanzania mainland. It has shown that use of mosquito nets reduces malaria transmission through mosquito bite (Figure 9) shows George W. Bush; a former president of U.S.A was in the campaign of addressing the use of mosquito nets in order to fight and reduce malaria deaths in Sub-Saharans countries including Tanzania.

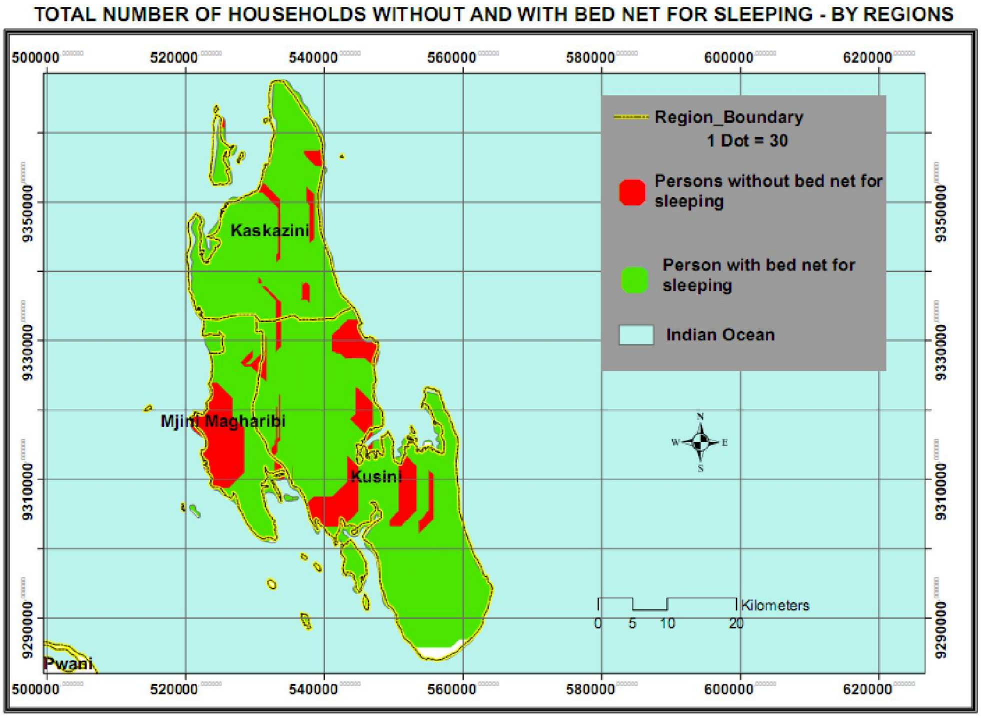

Figure 13. Spatial distribution of persons without and with bed nets for sleeping in Zanzibar. Year 2008.

Relating these results together with malaria cases, the regions which shows the highest number of persons tested malaria (*BS* ve+) and leading with highest number of death are those regions having high number of households without bed net for sleeping, those are: Iringa, Mbeya, Tabora and Tanga and Morogoro, Rukwa and Ruvuma regions.

However, in Dar Es Salaam the situation is contrary from other regions whereby the number of death is high for the persons with the age of 5 years old and above while the death below 5 years old declined, this is significantly show that in this region persons who are using bed net for sleeping are children below 5 years old as pointed out earlier. The comparison based on malaria cases between Tanzania mainland and Zanzibar are not provides in this work due to the lack of malaria cases data from Zanzibar.

From this result it's suggested that the best way of fighting against malaria is to focus and promote on the use of bed nets for sleeping in Tanzania mainland which has shown that most of households do not own mosquito nets for sleeping adults peoples or parents should also use mosquito net for sleeping in order to avoid malaria transmission among themselves.

TOTAL NUMBER OF PERSONS WITHOUT AND WITH BED NET FOR SLEEPING - BY REGIONS

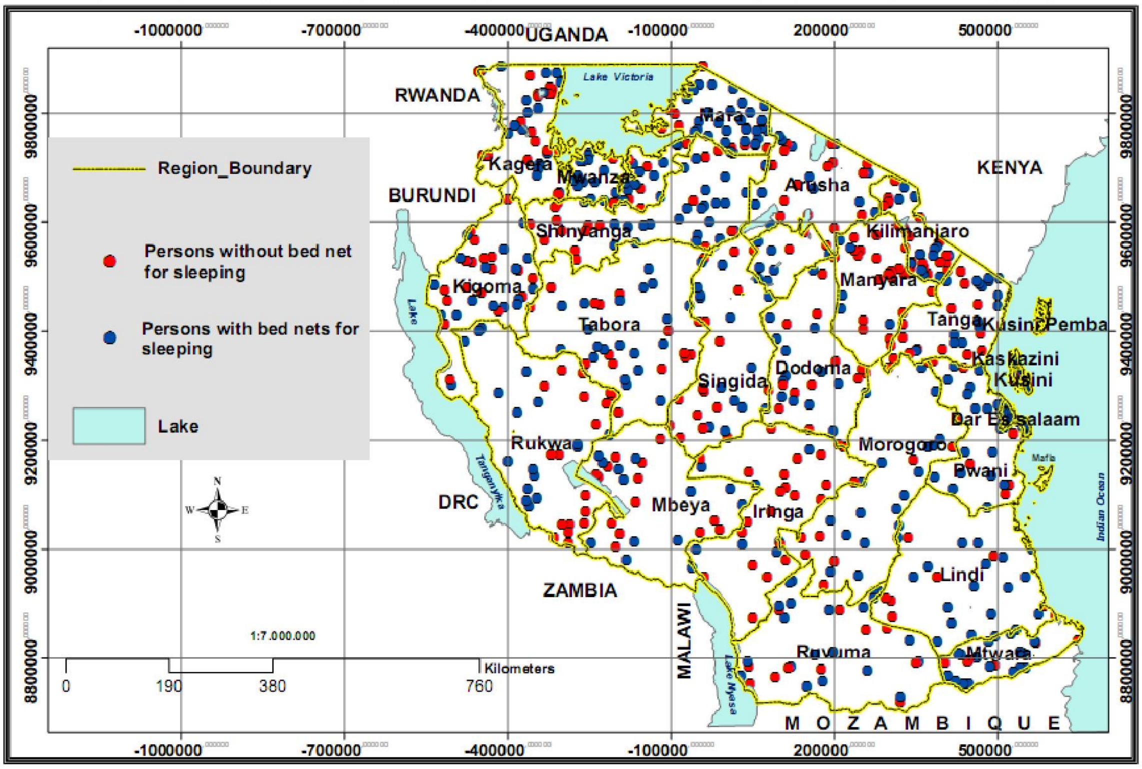

Figure 14. Spatial distribution of persons without bed nets and with bed net for sleeping. Year 2008.

4.4 Use of mosquito nets

The primary health intervention of reducing malaria transmission through mosquito bite during the night while slept is use of insecticide treated nets (ITN). This is the most effective way of fighting against malaria, if used properly and permanently. If possible large-scale introduction of insecticide-treated net (ITN) for the entire country has to be given high priority. It is also important that the mosquito nets should be available and affordable to the people, perhaps the Government can subsidize to the cost of buying the insecticide liquid which is always used to soak the mosquito nets once it is needed to do so especially after the previous insecticide period is expired. Use of bed nets is effective way at individual level by reducing biting intensities and provides protection against malaria (*Am. J. Trop. Med*, 2006). The life expectance of adult mosquito depends up on several factors; its gender, the temperature, the time of year and humidity levels as well. It is estimated that adult mosquito can survive from 3 days to 100 days. If shall be emphasized the use of ITN in order to cover large number of people this will reduce malaria at the household level due to the short life expectance of adult mosquito.

During the main farming season, most of families in rural areas leave their houses and stay in their farm-fields in temporal huts which contribute high level malarial infection. It's usually takes not less than four months until after harvesting due to crop insecurity, this period coincides with labour stress and difficulties access to health services, impossibility of using mosquito nets, family support and child care time at home (Hetzel *et al*, 2007).

An indicator called "households uses the insecticide treated bed net for sleeping" is defined from two variables associated to it: **if the persons did not use the insecticide treated bed net for sleeping** and **if the person used insecticide bed net for sleeping** with reference to the preceding of day of a Survey. Dot maps are provided for analysis, results and discussion.

4.4.1 Number of persons did not sleep under insecticide treated bed nets (Psuetb0)

This variable shows that most of households in Tanzania mainland never sleep under insecticide bed net (Figure 15).Tabora region is leading and is among of the regions constitute the highest number for death caused by malaria epidemic in the country. The coverage of using insecticide nets is very poor in the entire Tanzania mainland (Figure 15).

In Zanzibar the results shows that there are less persons who did not sleep under ever insecticide bed net except Kusini Pemba region which showed the highest number of households who did not use insecticide bed net for sleeping.

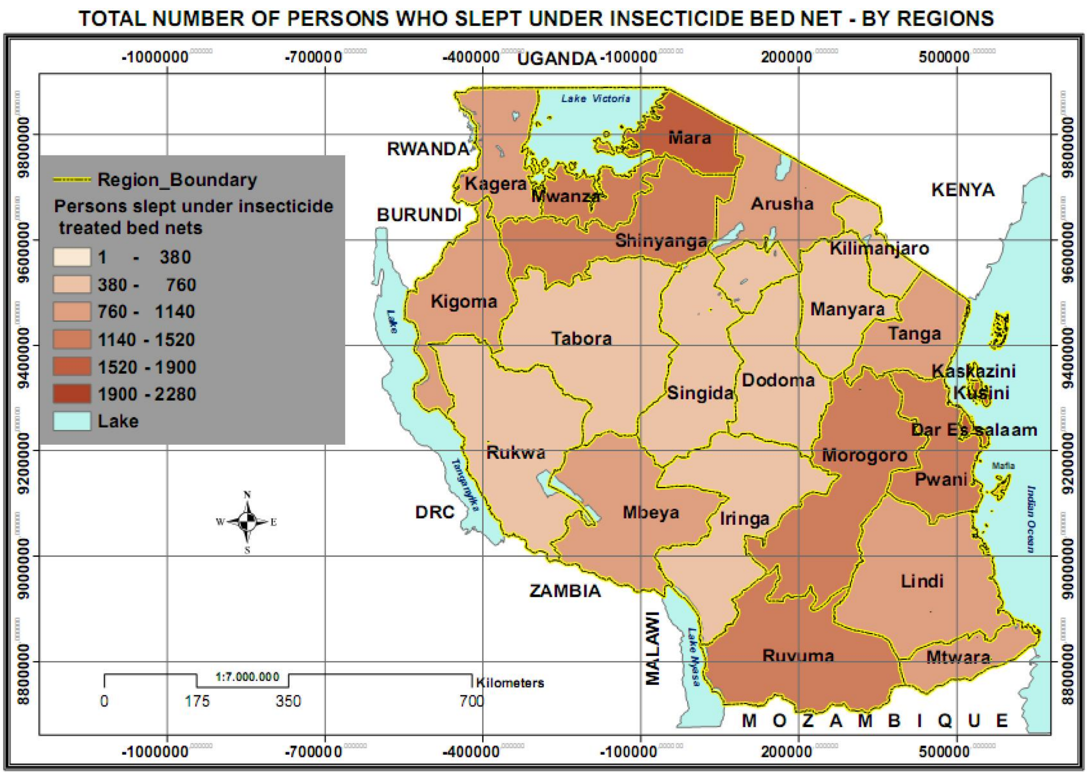

Figure 15. Spatial distribution of persons did not use insecticide bed net for sleeping. Year 2008.

4.4.2 Number of persons slept under insecticide bed net (Psuebt1)

This variable is aiming to obtain if the household uses the insecticide bed net for sleeping with reference to the day proceeding to Survey. In Tanzania mainland most of households in many regions are not using insecticide bed net (Figure 16). Mara region seems to be the one with the highest household's uses insecticide bed net for sleeping and this region has shown lower number of malaria case within the country (Figure 7 A). Dar Es Salaam region has shown with less number of households uses insecticide bed nets and has shown with high number of malaria cases. In the other regions like Tabora, Singida, Dodoma and Manyara, Kilimanjaro, Rukwa and Iringa there are very fewer number of household slept under insecticide bed net and these are malaria risk except Kilimanjaro and Singida.

In Zanzibar Island the situation is quite different compared to Tanzania mainland based on this variable. The coverage in Zanzibar is greater whereby many households slept under insecticide bed net and this means that in Zanzibar most of households use insecticide bed net while slept.

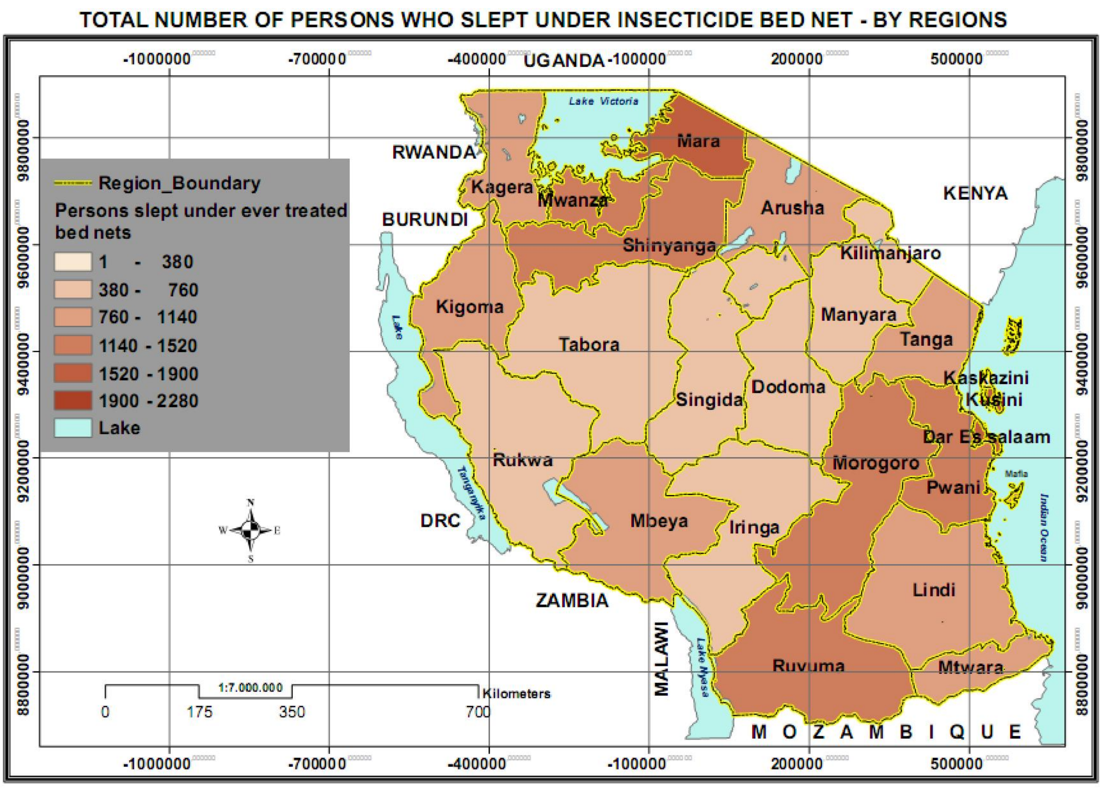

Figure 16. Spatial distribution of persons who used insecticide bed net for sleeping. Year 2008.

The results can be interpreted (Figure 17), where the spatial distribution of both variables shows that in Tanzania Mainland the variable **Persons did not sleep under insecticide bed net** dominate and malaria cases are high in many regions as well. The variable contributes to malaria transmission in most of the regions in Tanzania mainland whereas in Zanzibar **Persons slept under insecticide bed net** for sleeping dominate in two regions namely Mjini Magharibi and Kusini. In the region Kaskazini the results have shown that most of households does not use insecticide treated bed net for sleeping. There is a need for the government of Zanzibar to find out why most of households in this region do not use insecticide treated bed nets.

PERSONS DID NOT SLEPT UNDER INSECTICIDE BED NETS AND PERSONS SLEPT UNDER INSECTICIDE BED NETS BY REGIONS

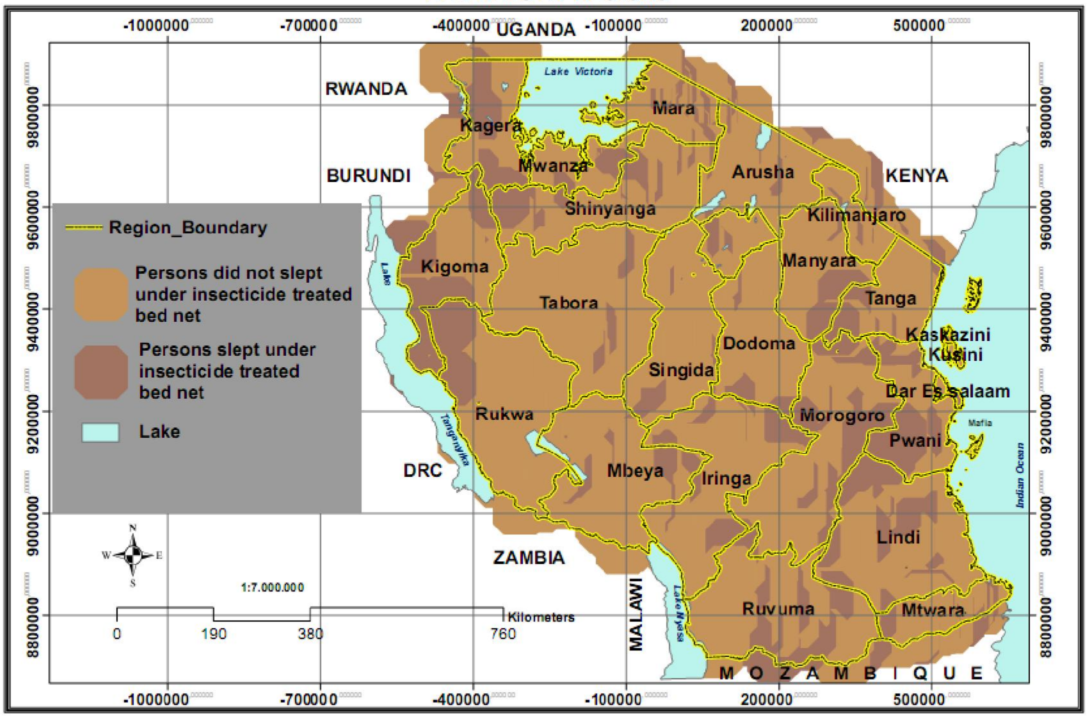

Figure 17. Spatial overlay of two variables: number of persons did not sleep under insecticide bed net and persons used insecticide bed net for sleeping. Year 2008.

Mara region shows to have many persons uses insecticide bed net for sleeping and the region shows to have fewer number of malaria cases. It has shown low total deaths caused by malaria epidemic with children's below 5 years old and 5 years old and above are few (Figure 8 B).

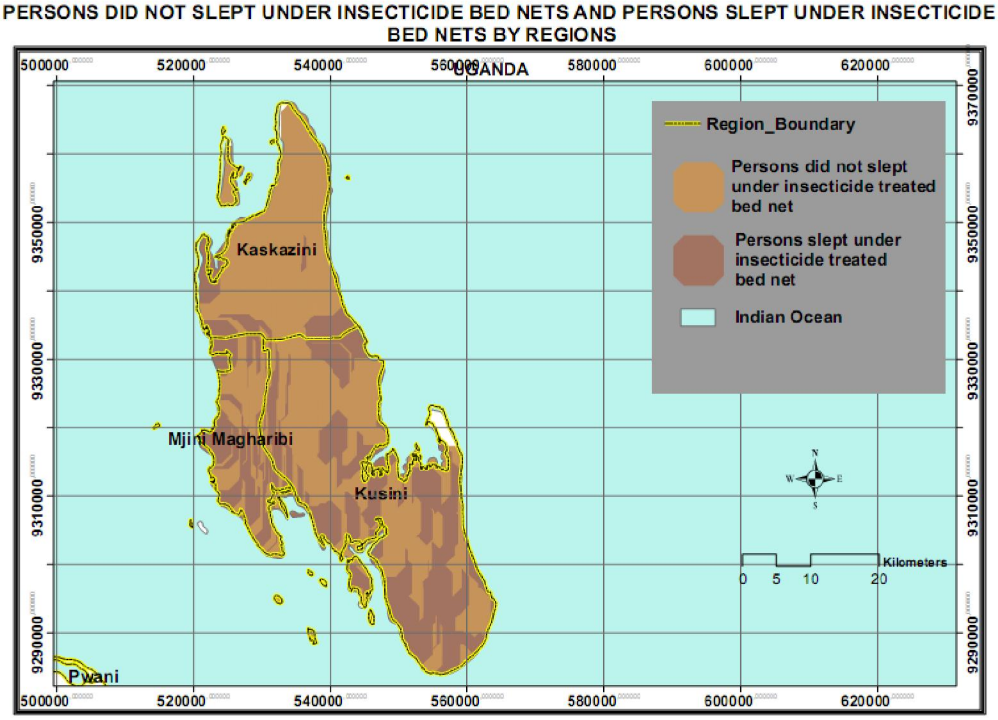

Figure 18. Spatial distribution of both variables in Zanzibar. Year 2008.

Approach to the impact of the disease based on these six variables have achieved, but is not easy to come up with the reasons which causes household not own and use of mosquito nets as well as insecticide bed nets due to the fact that there is no base data which can be used to derive this information.

Moreover, based on the above, there are might be some assumptions which need further study to be confirmed:

- Scarcity of availability of mosquito nets nearby peoples habitat, especially people who are living in the rural areas in comparison to people who are living in urban areas;

- Most of population of Tanzania is living below the poverty line (whereby the per capital income was 442$ in 2008);

- The logistics to supply the mosquito nets to the people are difficulties as in some of areas is not reachable due to bad condition of roads;

- Malaria is mostly transmitted during the rain and after the rain season (April-May), and the use of mosquito net may vary with respect to seasonal changes in rainfall and prevalence of malaria carrying mosquitoes; this data was collected between October and March which is a period of low rainfall and low levels of malaria transmission;

- Awareness among the people if they have knowledge on the importance of use of mosquito net, insecticide treated net in particular. Among others, these might be considered as one of the reasons as to why most of households have no mosquito bed nets for sleeping.

4.5 Indoor Residual Spraying (IRS)

Another way of reducing mosquito densities is by applying indoor residual spraying, it has shown rapid reduction of malaria transmission and mortality rate. In order to reduce the incidence of malaria in the indentified areas indoor residual spray should be conducted in at least 85% of households (WHO, 2005).

This exercise cannot be done once, it has to be done regularly so that to maintain effectiveness against mosquitoes. Also the spraying depends up on the availability of insecticide, how efficient they are as well as affordability. If the insecticide used is weak therefore the frequency of spraying will occur severally, but if strong insecticide was used, the frequency of applying IRS will be very low. *Lambda Cyhalothrin* spraying is powerful insecticide which can be applied and should be repeated approximately twice a year for a better result (WHO, 2005). Indoor Residual Spraying started earlier in Zanzibar to be practiced (Figure 19) show The U.S. Secretary of Health and Human Services, Michael O. Leavitt by then is participating in the exercises in Zanzibar in order to motivate the local to keep on spraying against mosquitoes as one of the way to eradicate malaria epidemic in the country.

Figure 19. The U.S. Secretary of Health and Human Services, Michael O. Leavitt (right) participate in an indoor residual spraying campaign against malaria in Zanzibar.

Two variables were considered and selected based on the indoor residual spraying characteristic which includes:

4.5.1 Number of household did not spray against mosquito in the last 12 months (Hsamil120)

Spatial distribution are performed based on this variable and after data analysis it show that about 96% of households of total population of Tanzania mainland did not spray against malaria over last 12 months in all regions. On the opposite, Zanzibar showed fewer numbers of households did not spray against malaria over last 12 months (Figure 20).

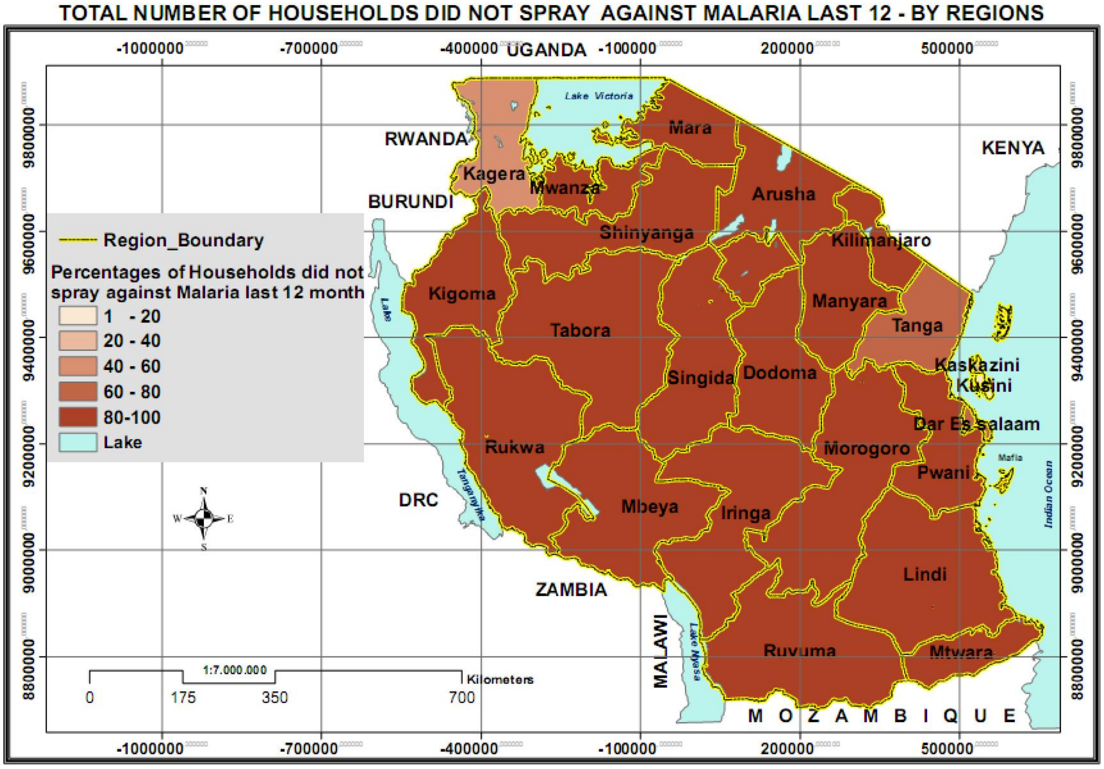

Figure 20. Spatial distribution of households who did not spray against malaria over last 12 months. Year 2008.

4.5.2 Number of household sprayed against mosquito in the last 12 months (Hsamil121)

Based on the variable; called Number of household did not spray against mosquito in the last 12 months, it has shown that in Tanzania mainland it has received little attention. Effective implementation of IRS with other recommended insecticides should be a central part of national malaria control strategies where this intervention is appropriate.

Spatial distribution analysis based on this variable shows that very fewer regions in Tanzania mainland sprayed against malaria over last 12 month. Kagera, Tanga and Dar Es Salaam shows some few households sprayed against mosquito in Tanzania mainland which is accounts to 3-4% of households of total population in the country (Figure 21). These three regions are among of the regions with the highest number of malaria deaths; Kagera region leading with deaths among children's under 5 years old, while Dar Es Salaam leads with highest number of deaths among persons with age of 5 years old and above.

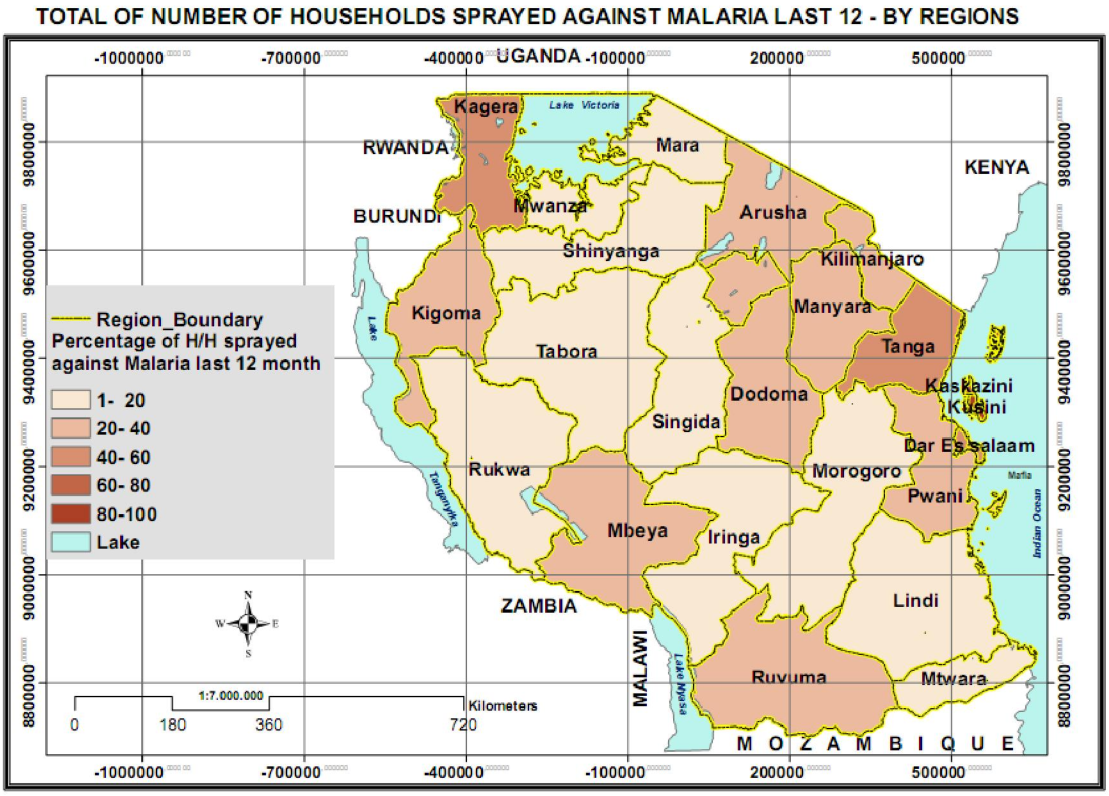

Figure 21. Spatial distribution of Household who sprayed against malaria over last 12 months. Year 2008.

In comparing Tanzania Mainland and Zanzibar the results shows that most of regions in Zanzibar 85% of total population sprayed their households over last 12 months.

In Zanzibar the spraying against malaria is often done within 12 month. This practice is dominating in most of the regions as can be depicted (Figure 22) which shows the results after spatial overlay being performed.

Spatial overlay is carried out using both variables and the essence of doing so is to determine the variable which dominate mostly in each particular region in the entire country as can be shown in Figure 23, the variable households who do not spray against malaria dominates in mostly of the regions in Tanzania mainland except in Kagera, Tanga and Dar Es Salaam regions. The emphasis on applying IRS is important in order to reduce malaria transmission throughout the country.

HOUSEHOLDS DID NOT SPRAY AGAINST MALARIA LAST 12 MONTH AND SPRAYED AGAINST MALARIA LAST 12 MONTH - BY REGIONS

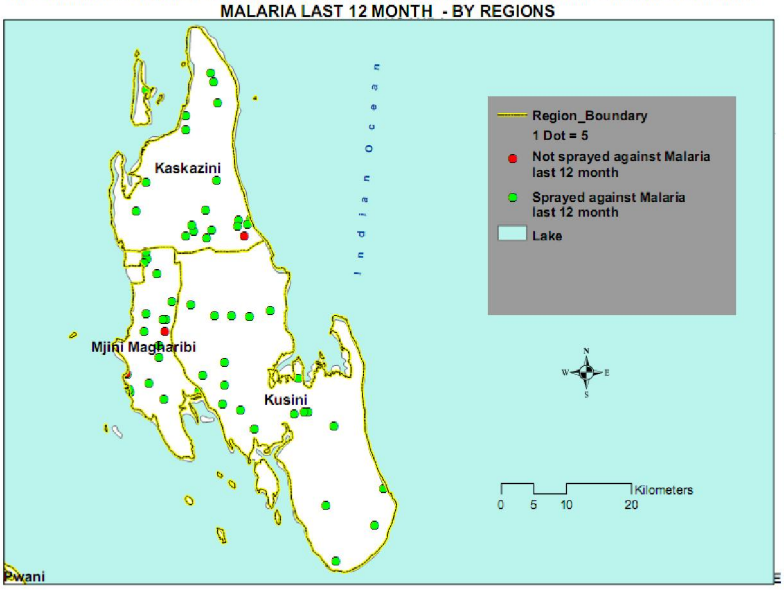

Figure 22. Spatial distribution of both two variables in order to determine which one is contributing most to Malaria. Year 2008.

HOUSEHOLD DID NOT SPRAY AGAINST MALARIA LAST12 MONTH AND SPRAYED MALARIA LAST 12 MONTH

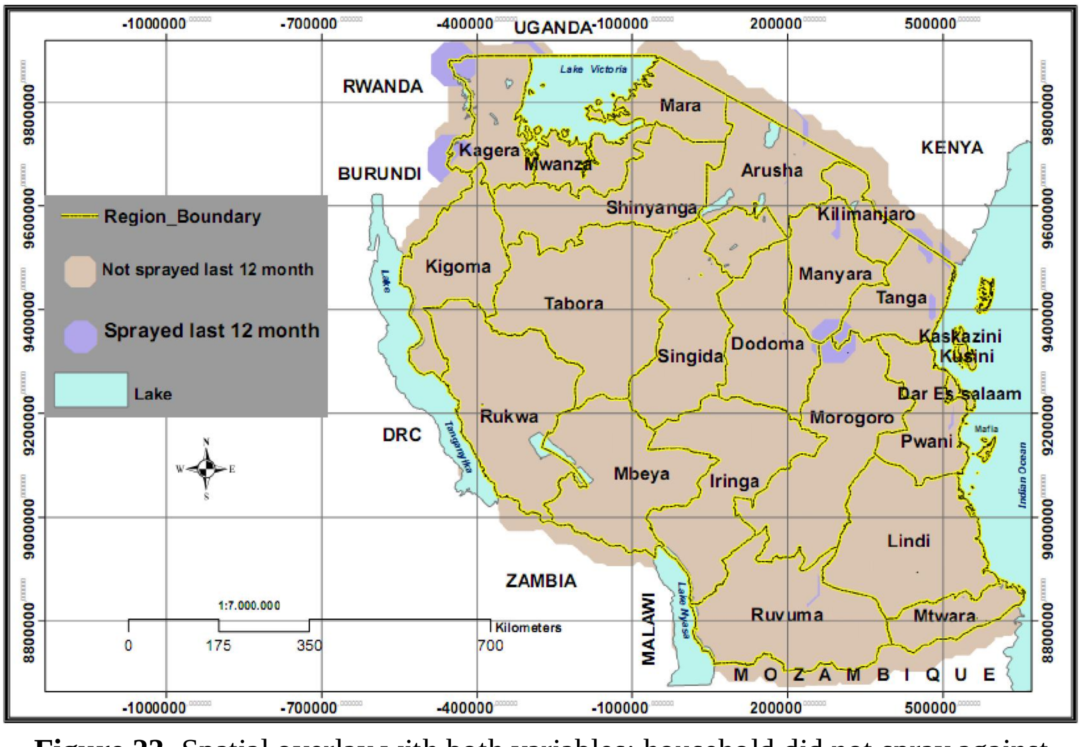

Figure 23. Spatial overlay with both variables: household did not spray against malaria and household spray against malaria over last 12 month. Year 2008.

4.6 Areas which are most favourable to mosquitoes breeding

Malaria transmission is highly related to the natural factors such as temperature, rainfall and topography (Lindsay and Martens, 1998). Apart from the climatic and ecological conditions, rivers, floodplain, manmade open wells and gardens close to home, valleys, latrines and perennial just to mention a few and some other factors related to that kind of nature have shown to be favourable areas for mosquito breeding: source of water, toilet facilities (Hetzel *et al*, 2007) (Figure 24).

Transmission reducing interventions should therefore be timed before the rain associated increase in mosquito breeding and target households located near the rivers, ponds, flood plain and other targeted area which seem to favour mosquito breeding.

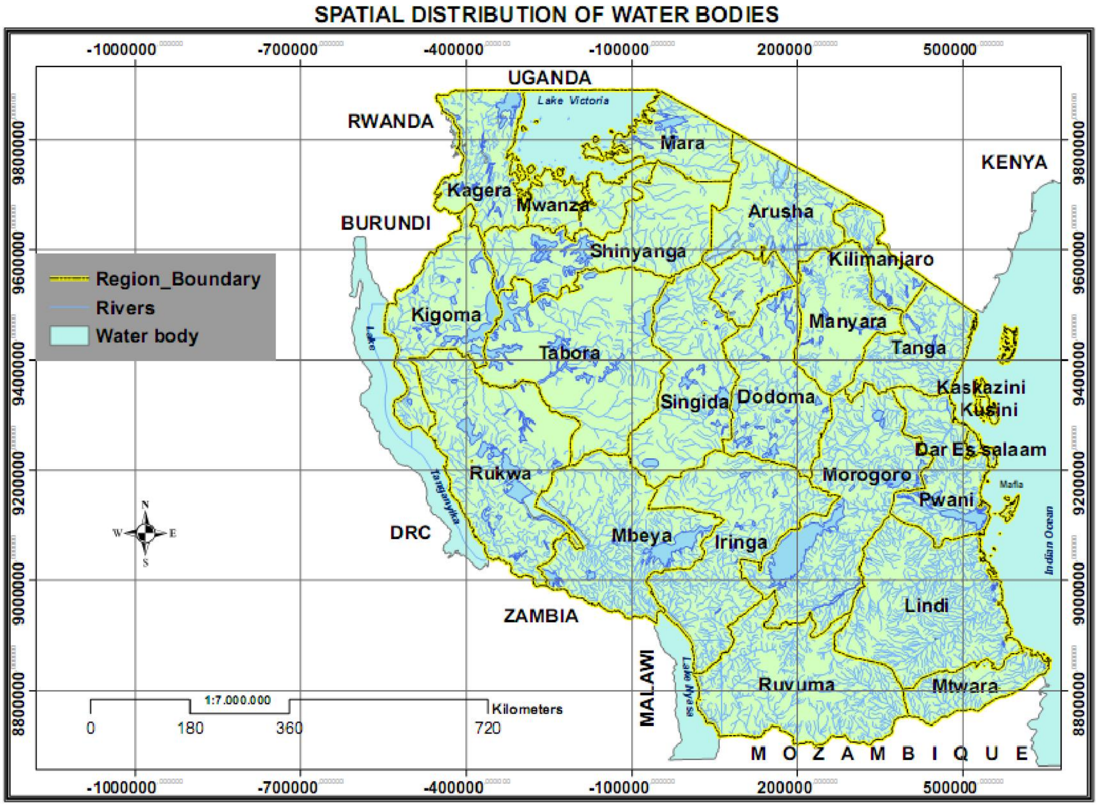

Figure 24. Distribution of water bodies in Tanzania which are favourable for mosquito breeding. Year 2008.

The following variables are considered as the most areas which are favouring mosquito breeding.

4.6.1 Number of households living close to piped into dwelling (SW11)

The piped dwelling is one of source of water used by several number of households lives nearby. The number of households which depend on one pipe are not fixed varies from place to place and might serve more than ten households or less. The important factor is that if a household lives close to the water pipe is eligible to fetch water from that water pipe. Piped close to dwelling is the government initiative to bring close the source of water facility especially to the people who are living close from each other but unfortunetely the area where pipe is constructed there is no enough care for cleaning nearby area which results water shed close to the pipe and sometimes grassess close to the pipe area as result mosquito uses this opportunity to lay their eggs in that area and increase mosquito densities and this was among other reasons lead to consider this variable as among of the variable shift malaria vector.

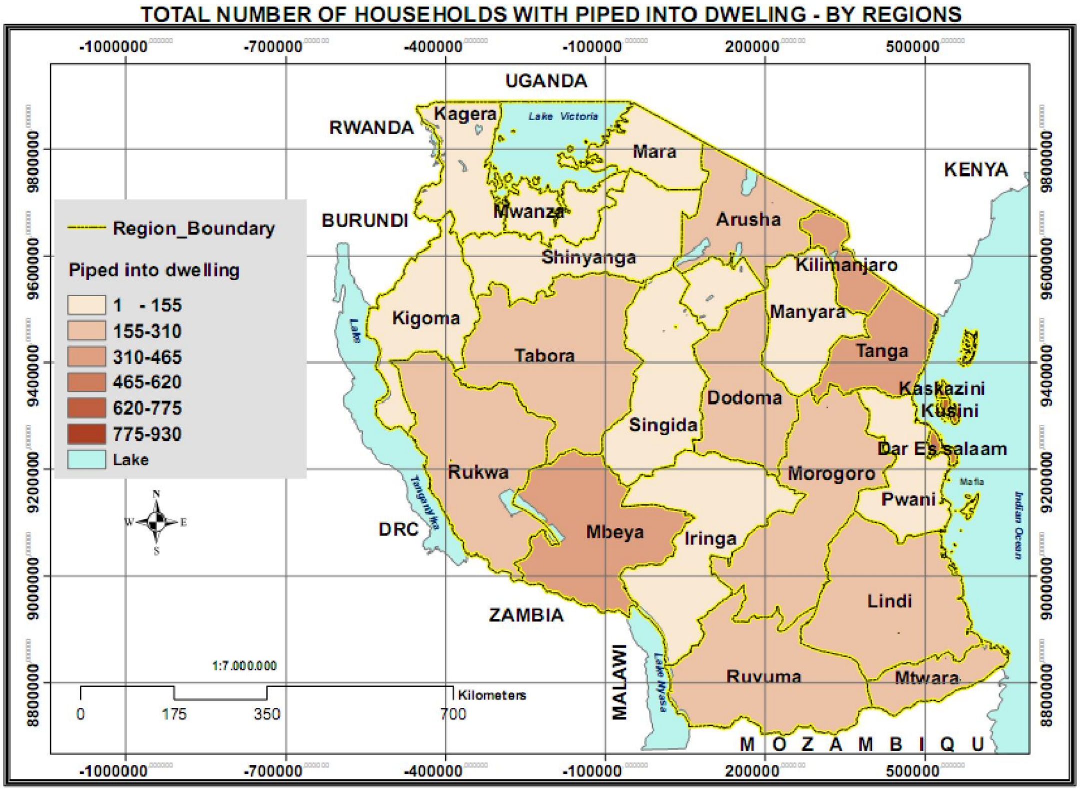

Figure 25. Spatial distribution of households living with water piped in dwelling. Year 2008.

The analysis based on this results are Dar Es Salaam region is leading with high number of households lives close to piped into dwelling followed closely by Tanga, Mbeya and Kilimanjaro (Figure 25). Malaria cases in these regions are many as have already noted out previously. Thus, this variable should be accounted as one of main variables contributing to malaria epidemic.

In Zanzibar the regions Kusini Pemba and Mjini Magharibi have shown with highest number of household's living close to water piped into dwelling (Figure 26).

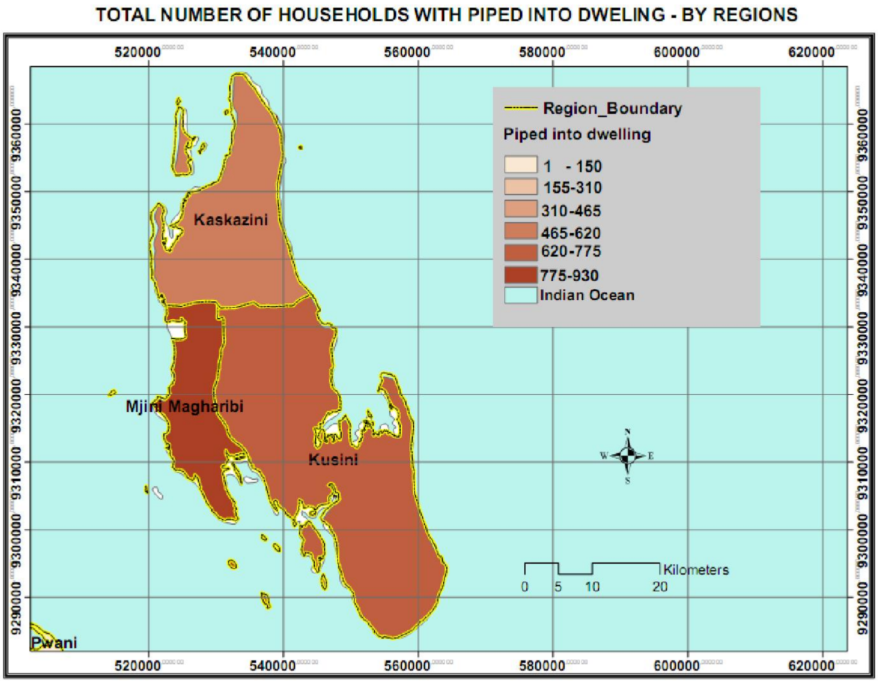

Figure 26. Spatial distribution of household with piped into dwelling in Zanzibar. Year 2008.

According to this result Zanzibar has more households living close to water piped into dwelling compared to Tanzania mainland (Figure 26). This variable can be considered as a variable that contributes to malaria epidemic in Zanzibar. In Figure 27 show the pool of water surrounding the water tape in short period of time and many bucket are waiting to be filled with water the muddy and dirt favour mosquito breeding.

Figure 27. Minister of water and Irrigation Prof Mark. M officiating Piped into dwelling in Kibaha district Tanzania mainland. Year 2010.

4.6.2 Number of households living with piped within yard or plots (SW12)

The difference with the previous variable is that piped into Yard or Plots serve only one household and is constructed inside a Plot or a Yard into that respective household. Normally might be categorized and grouped similarly to latrines, garden within a household and if it is not well treated might become a place which produces mosquitoes breeding especially watershed surrounding the pipe into the yard.

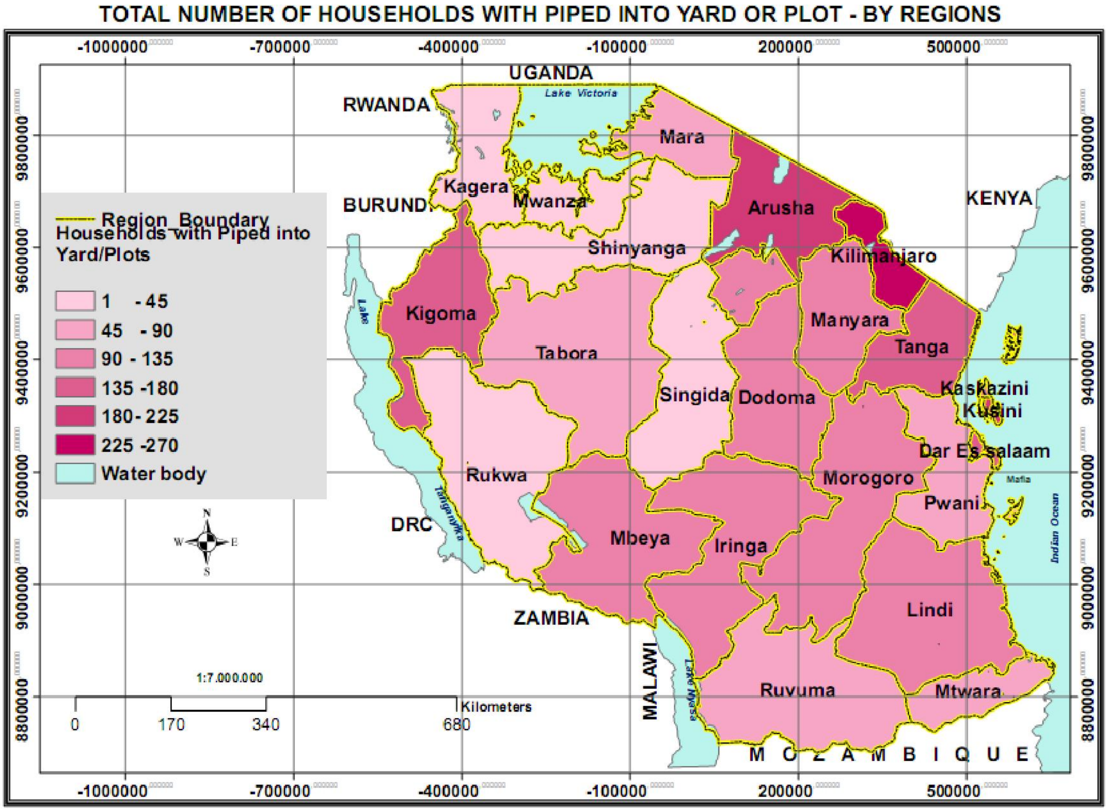

Figure 28. Spatial distribution of household's lives with piped into Yard or Plots. Year 2008.

The results after analysis show that Kilimanjaro region is leading followed closely by Arusha and Kigoma (Figure 28). These regions have shown low malaria cases except Kigoma region which has shown high malaria cases. In Zanzibar this variable declined compared with water pipe into dwelling.

As can be interpreted in Figure 29 overlay analysis, the variable household's lives close to water piped into dwelling dominated in almost of the region in Zanzibar whereas a variable water pipe into Yard or plots dominated in Tanzania mainland. Based on this results the variable which contribute mostly to malaria disease in Tanzania mainland is water piped into yard or plots; meanwhile in Zanzibar and Dar Es Salaam the important variable is piping into dwelling (Figure 30).

HOUSEHOLDS LIVING CLOSE TO PIPED INTO DWELLING AND PIPED INTO YARD

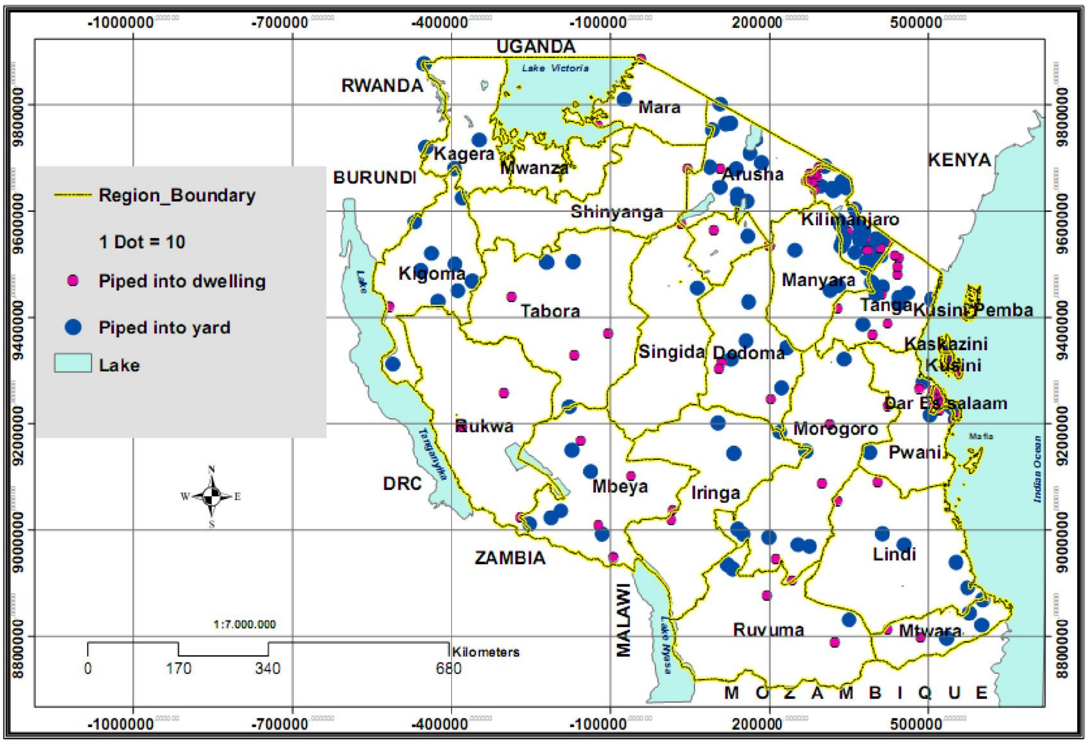

Figure 29. Spatial distribution of both variables piped into dwelling and piped into Yard or Plot. Year 2008.

HOUSEHOLDS LIVING CLOSE TO PIPED INTO DWELING AND PIPED INTO YARD - BY REGIONS

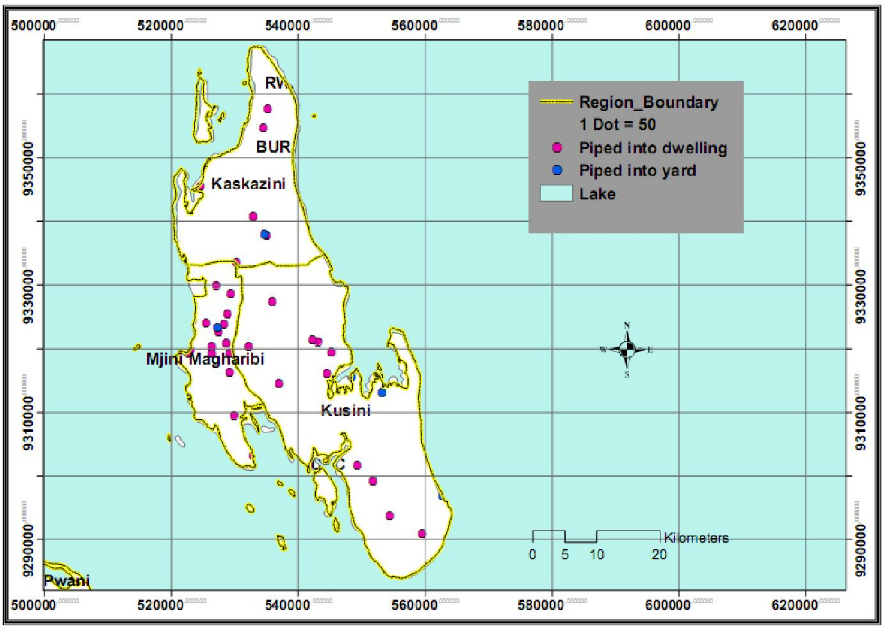

Figure 30. Spatial distribution of both variables in Zanzibar. Year 2008.

4.6.3 Number of households living close to the rivers or water stream (SW42)

The mosquito vectors require stagnant water to complete its life cycle: which is as follows; egg, larva, pupa, and the adult. The adult female my lay between 200-1000 eggs, the quantity is influenced by the amount of blood in taken. Blood feeding usually starts at dusk and continues until dawn (Ethiopia, 2005).

According to the study carried out in 2006 based on “Spatial and temporal variation in the malaria transmission in a low endemicity area in north Tanzania local malaria transmission is restricted to the rainy season and strongly associated with proximity to the river (Oesterholt *et al*, 2006).

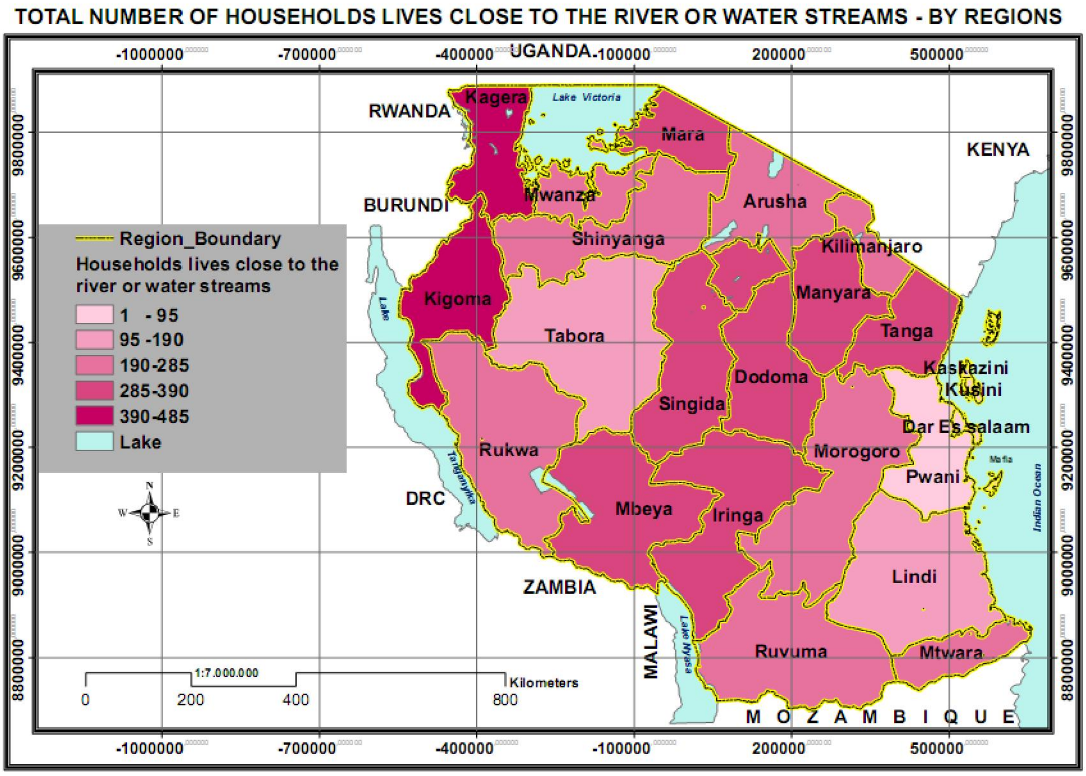

Figure 31. Spatial distribution of households lives close to rivers or water streams. Year 2008.

Kagera and Kigoma region have high number of household’s living close to rivers or water streams (Figure 31). As pointed out previously, the incidence of malaria cases is very high in Kagera region with highest number of deaths for the children under 5 years old, while Kigoma has more malaria incidence among the person with 5 years and above. Other regions includes: Iringa, Mbeya, Singida, Tanga and Manyara have shown with many households lives close to the rivers or water streams and the impact of malaria cases in these regions are very high as well. In Zanzibar and Dar Es Salaam region there are fewer number of households living close to rivers and water streams, this is because of scarcity of rivers in those areas so does not contribute much to malaria epidemic.

4.6.4 Number of households lives close to the ponds, Food plain or lakes (SW43)

The breeding sites of infected mosquitoes vary greatly with regards to species. Some prefer clear water, inhabiting the edges of streams, while others thrive in irrigation ditches and reservoirs. Permanent natural bodies of water, such as swamps and flood plains serve as unique breeding grounds (Walsh *et al*, 1993). Some species require extensive vegetative cover, preferring swamps and other permanent water bodies laden with dissolved organic matter. Mosquito breeding sites are found anywhere in fresh water collects. In fact, there is a direct correlation between the availability of water and the frequency in which mosquitoes feed on humans (Walsh *et al*, 1993).

This analysis show that Mara and Singida regions have high number of household lives close to ponds and flood plain (Figure 32), while relating these results with malaria cases both regions have reported with malaria cases (Figure 7A). Other regions have high number of household's lives close to the ponds and flood plain as well as malaria cases are high within those regions.

In Zanzibar fewer households lives close to ponds and flood plain. This variable does not contribute much to Malaria epidemic in Zanzibar compared to Tanzania mainland.

HOUSEHOLDS LIVES CLOSE TO THE PONDS, FLOOD PLAIN OR LAKES - BY REGIONS

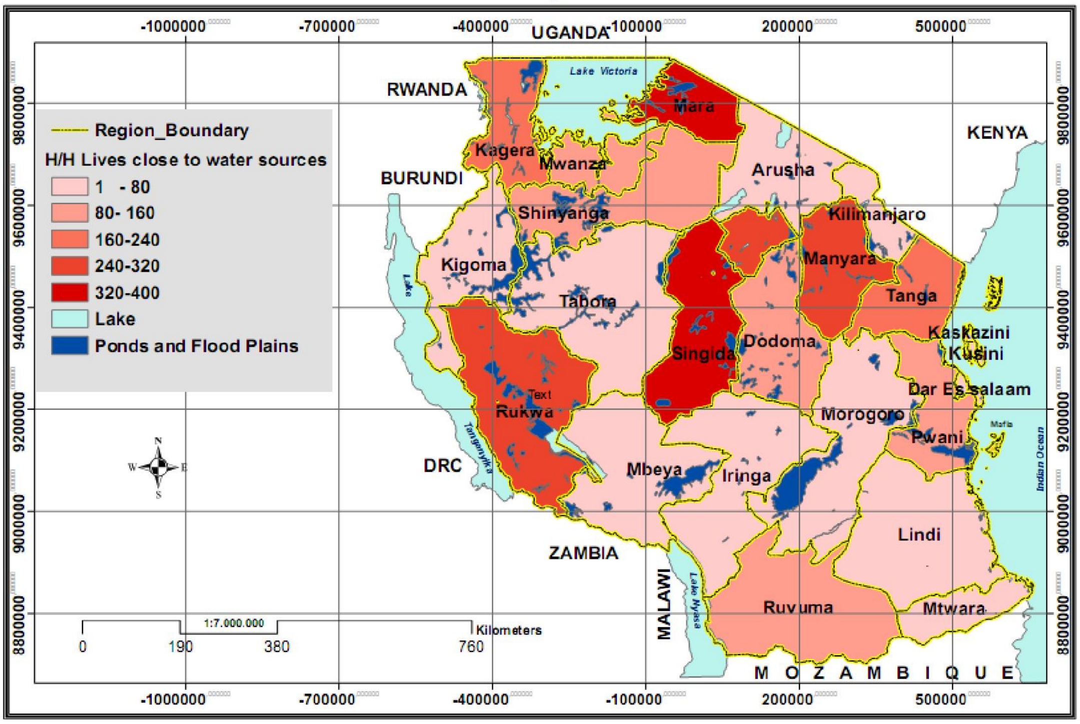

Figure 32. Spatial distribution of the variable number of household living close to Ponds, Flood plain or lakes. Year 2008.

Households living close to flood plains, ponds and Lakes are susceptible to malaria attacks compared to the households lives far from these areas.

The overlay analysis results based on these two variables show that the variable **(SW42)** dominates in almost of all regions in Tanzania mainland; while in Zanzibar there are fewer households lives close from both variables (Figure 33). This variable should be counted as the major variable which contributes to malaria transmissions in almost of each region in Tanzania mainland. Mara and Singida regions both variables seem to contribute equally to malaria transmission (Figure 33). The mechanism in fighting against malaria within these two regions should consider both variables as mosquito vector and contributing to malaria epidemic in these two regions.

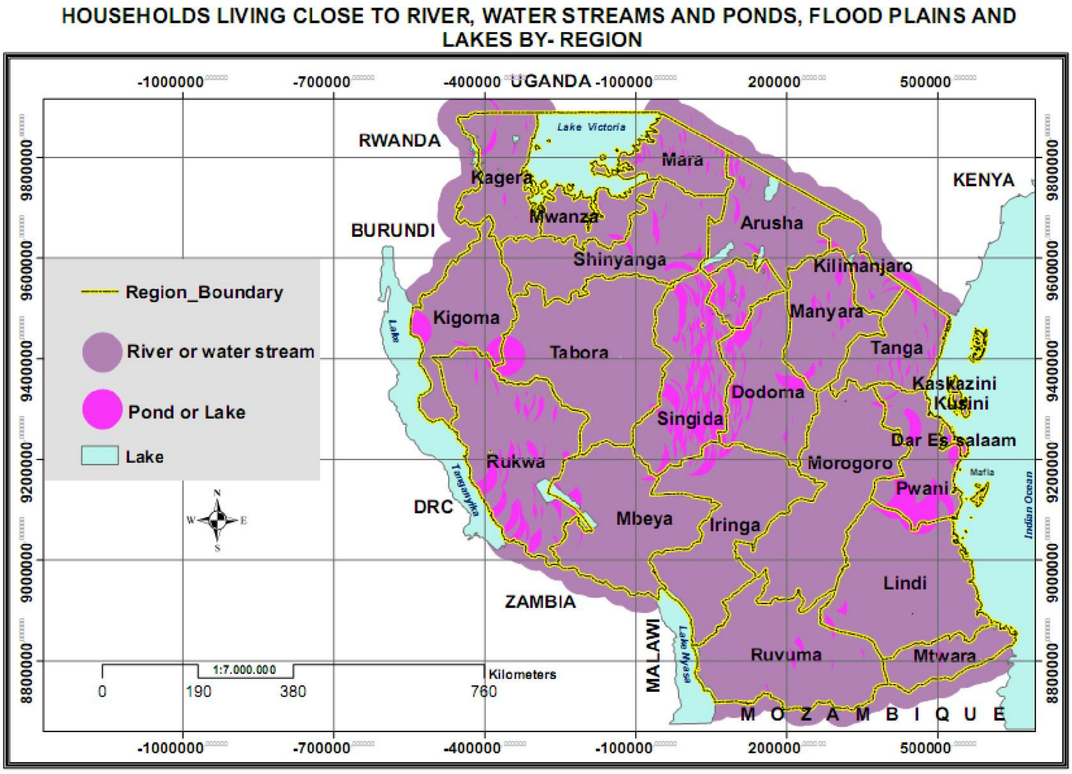

Figure 33. Spatial overlay of both variables, households lives close to rivers or water streams Pond and lakes. Year 2008.

4.6.5 Number of households living close to neighbour having open well (SW24)

Some of the households possess an open well as source of water. Also the owner uses wells to sell water to the neighborhoods. It occurs mostly in urban areas which are populated and water sources are the major problem in those areas. Usually open well is unprotected properly because it is not covered and mosquito uses this type of well to lay their eggs and multiply.

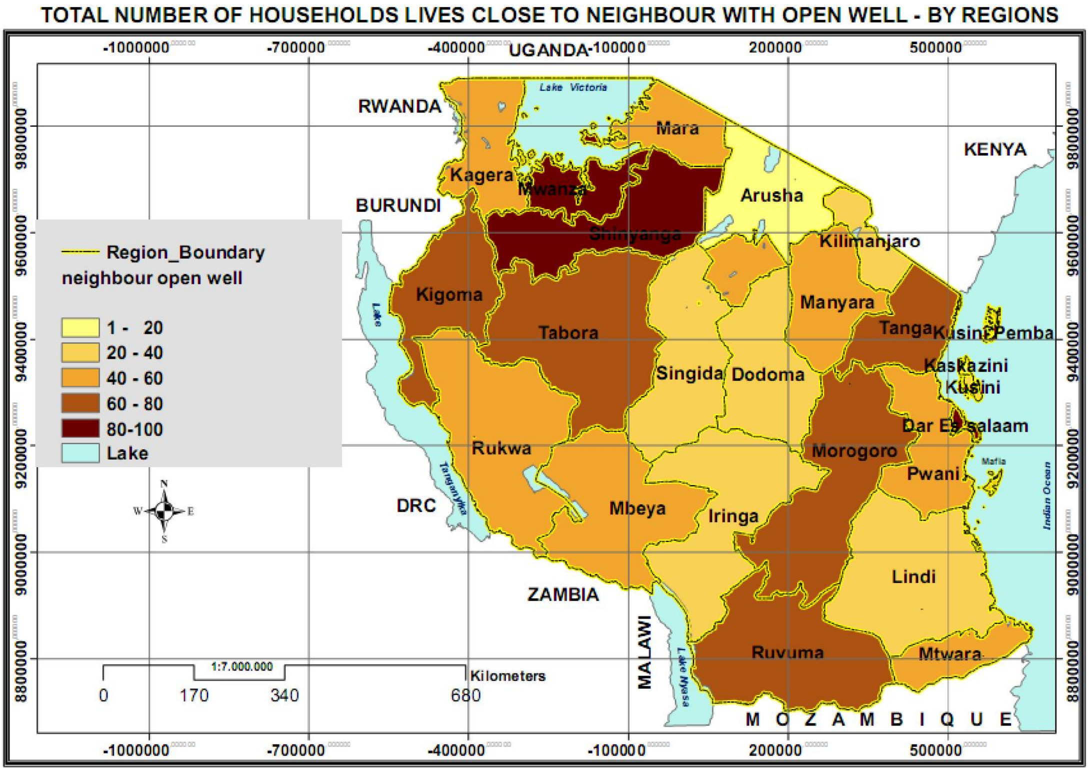

Figure 34. Spatial distribution of Households living close to a neighbour with open well. Year 2008.

As shown on (Figure 34), Mwanza, Shinyanga and Dar Es Salaam have more households living close to a neighbor with open well. Dar Es Salaam and Mwanza are the major big cites in Tanzania and have reported with high intensity of malaria cases in this regards, this variable should be counted as vector malaria risks in these regions. Kigoma, Tabora, Ruvuma and Morogoro, Tanga are the second regions with household's lives close to the neighbor with open well and malaria incidences in these regions are many as already discussed previously. Thus, this variable relates significantly to malaria transmission in these regions. In Zanzibar there are fewer households' lives nearby a neighbor whose possessing an open well and therefore this variable does not contribute much to Malaria disease in Zanzibar.

4.6.6 Number of households living with open wells in the yard and public open well (SW22, SW23)

Construction of water control projects can also lead to shifts in vector mosquito populations. Reservoirs, irrigation canals, wells and dams are closely associated with the increase of a variety of parasitic diseases that are water dependent. Throughout the world, especially in developing countries, dams, wells and other related water projects continue to be planned, constructed, and operated to meet human needs such as drinking water, energy generation, and agricultural production.

In Tanzania, the government has been insisting the construction of dams and wells in order to serve population as source of water Facilities. The experience shows that once a well has constructed there is no care measures to keep clean the environment surrounding the well, water shade in the surroundings and grasses this waste water when takes long dug in the dirt, and they quickly become muddy and clogged with waste and the area become wet throughout and pools of water and waste form in the surrounding once they are clogged, and this is where mosquitoes lay their eggs.

Spatial distribution of this variable is carried out in order to determine the regions which are most affected from malaria epidemic whereby the source is (SW22, SW23) variable (Figure 35).

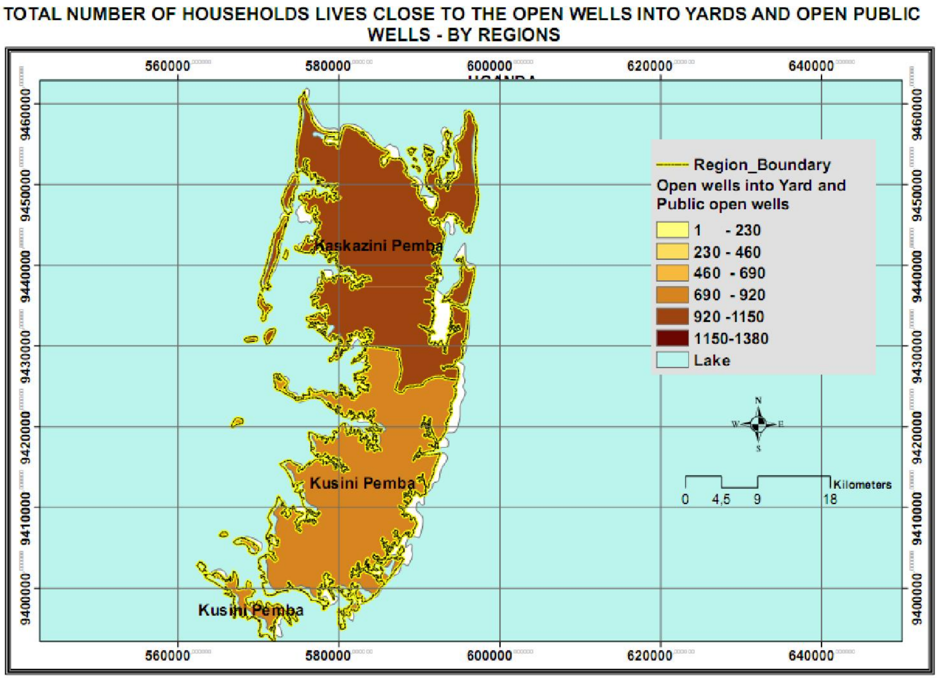

Figure 35. Spatial distributions of households living close the open well into Yard and open public wells in Zanzibar. Year 2008.

The results shows in Zanzibar, Kaskazini Pemba region has a greater number of household's who live close to the open public wells compared to other regions.

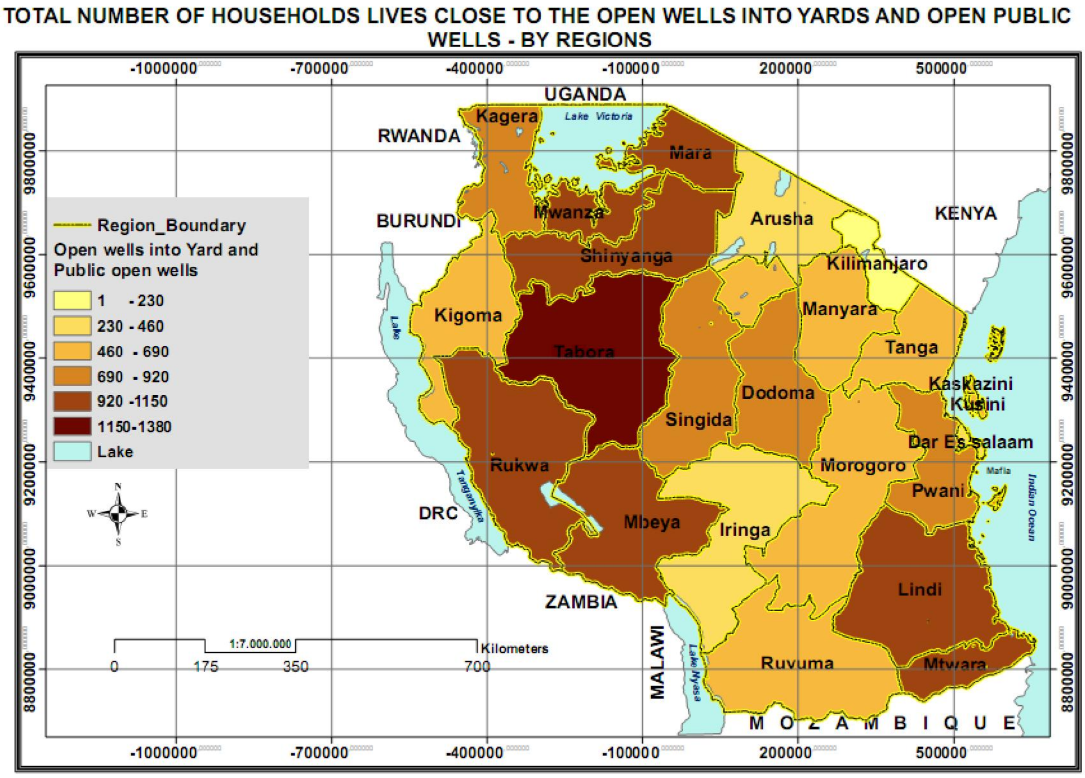

Figure 36. Spatial distribution of households living close to the open public well and open well into Yard. Year 2008.

Tabora region is leading with the highest number of household's living close to open public wells and open wells into Yards (Figure 36). It is followed closely by Mwanza, Shinyanga, Rukwa and Mbeya, Lindi Mtwara and Mara regions. In these regions malaria cases is very high as reported by (MOH, 2006). The spatial distribution of this variable as can be seen (Figure 36) shows that this variable is distributed highly in the most of the regions in Tanzania mainland.

Spatial overlay analysis is shown on (Figure 37) where open public well dominated in most of all the regions compared to neighbor with open well. Based on these results, variable household's lives close to public open wells contribute mostly to malaria transmission in Tanzania mainland.

In Tanzania Zanzibar there are fewer households lives close to public open well and household's lives close to a neighbor with open well.

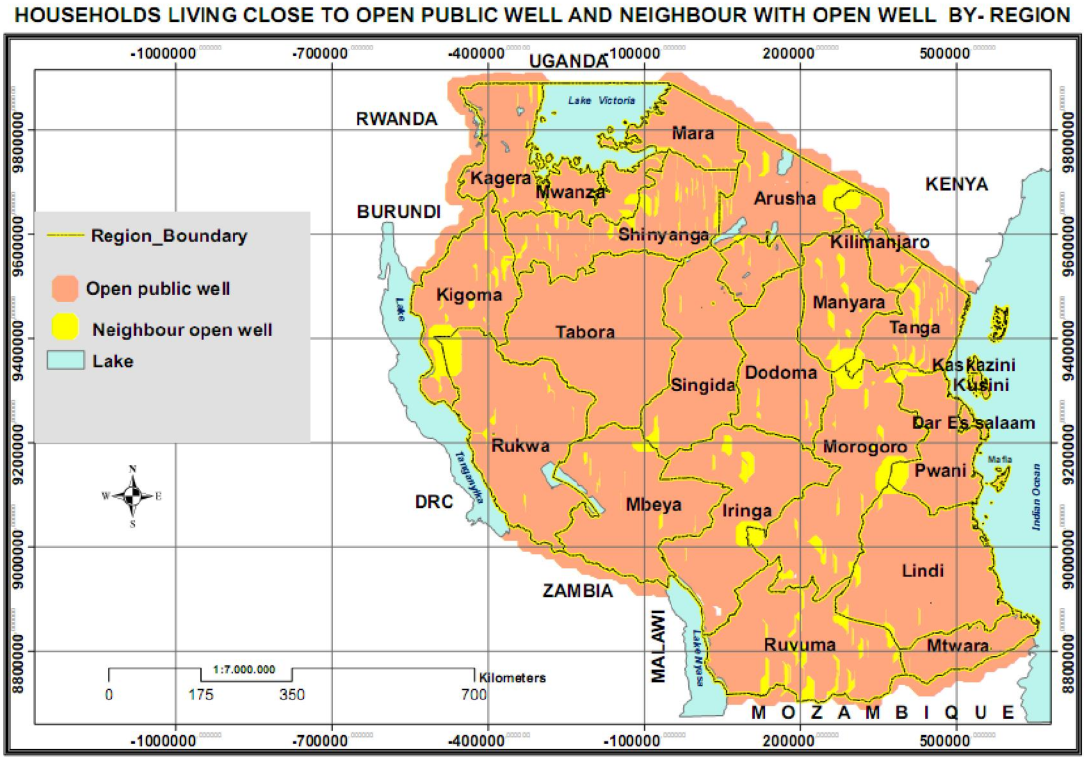

Figure 37. Spatial overlay between two variables household living close to open well and a neighbour with open well. Year 2008.

4.7 Use of SPSS software

Analysis of all seventeen variables does not end up on the use of ArcMap and R, software's but also, SPSS is deployed as part of analysis and only one method is used while working on this software in order to group the variables which are homogeneous. **Averaging Linkage (Between Groups**) is performed based on seventeen variables and the analysis yielded the results which shows that four clusters based on seventeen variables are formed (Figure 38).

The first cluster comprises all Zanzibar regions and two regions from Tanzania mainland Iringa and Mara regions. The analysis shows that Zanzibar is at low risk of malaria occurrence since fighting against malaria have started taken care whereby variables like; number of persons with bed net for sleeping; indoor residual spraying and persons uses insecticide bed net dominated in almost of all regions in Zanzibar and also the government of this country is empathize in fight against malaria and has subsidized the price of buying the mosquito net in order to motivate the local. Mara region is in this cluster also has shown low level of malaria cases whereby 40% of total population in this region are using mosquito bed nets while Iringa region which is in this cluster is among of regions with high malaria cases in Tanzania mainland.

The second cluster represents regions reported with malaria cases as well, but not among the regions with high number of death caused by malaria disease as already seen previously.

The third cluster comprises those regions that have shown with high number of households without bed net, households did not spray against malaria over last twelve month and constitute high number of household's lives close to the open wells and high number of household's lives close to the rivers and streams. This cluster represents regions with high malaria cases in Tanzania mainland.

The fourth cluster comprises only one region Dar Es Salaam where malaria cases is very high with highest total deaths among persons with 5 years old and above and decline for the death of children's below 5 years old. Most of variables have shown to contribute to malaria transmission in this region this might be taken as to why has shown peculiar behaviour from other regions.

Dendrogram
Model

H I E R A R C H I C A L C L U S T E R A N A L Y S I S
Dendrogram using Average Linkage (Between Groups) Rescaled Distance Cluster Combine

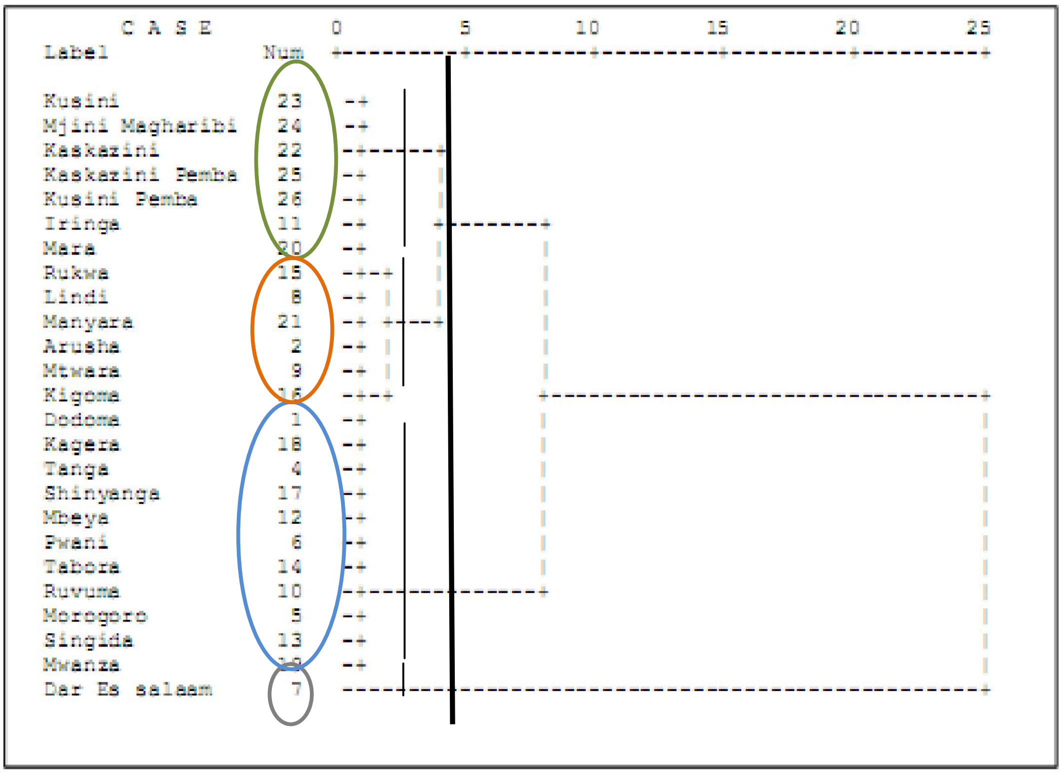

Figure 38. Dendrogram using averaging linkage between groups. Year 2008.

4.8 Indicator based on Housing conditions

Finally as mentioned earlier that housing conditions characteristics are used in this work and two indicators are worked on, to concretize the final results which are; the most favourable mosquitoes breeding areas associated with water and have already discussed and Toilet Facilities.

4.8.1 Toilets which are favouring mosquito breeding

Most of households in Tanzania are using various types of latrines as toilet facilities and most of these are traditional pit latrines. The improved latrines like flush toilets are not possible to be utilized due to poor infrastructure based on sanitation and sewerage disposal. Fewer households found in the cities are using improved flush toilets mainly in Dar Es Salaam, Mwanza, Tanga and Arusha.

Traditional latrines toilet (Figure 39) is a hole covered part of it and on top of it a small hole is usually left uncovered in order to allow trashing when a person is in use of the toilet. This kind of toilets are used in serving many purposes for example is used also as bathroom and once water used while taking shower goes directly in the hole through small opening left uncovered. As pointed out earlier mosquito vector requires water and dissolved organic matter to complete its life cycle. Household's lives close to the latrines are at risk of contacting malaria disease **(**Kirby *et al*, 2008).

Figure 39. Traditional latrines which usually contribute to malaria transmission

There are several types of latrines but in this work, three variables based on toilet facilities were considered which are;

- Number of household's lives close to traditional pit latrines (TF22)
- Number of households use bush/ field as Toilet facility TF41)
- Number of households using poor/flush toilets (TF11)

4.8.2 Number of households with Traditional Pit latrines (TF22)

Pit latrines are used in most of habitat in Tanzania as a source of toilet facilities in both rural and urban areas due to poor infrastructure based on sanitation sewerage disposal as mentioned earlier. In addition, poor excreta disposal and inadequate water supply have contributed to high incidences of malaria transmission. There are several scientific evidence which have already done in various countries the results has shown that most of household lives close to the latrines are at high risk of contracting malaria epidemic compared to those lives far from latrines (Kirby *et al*, 2008).

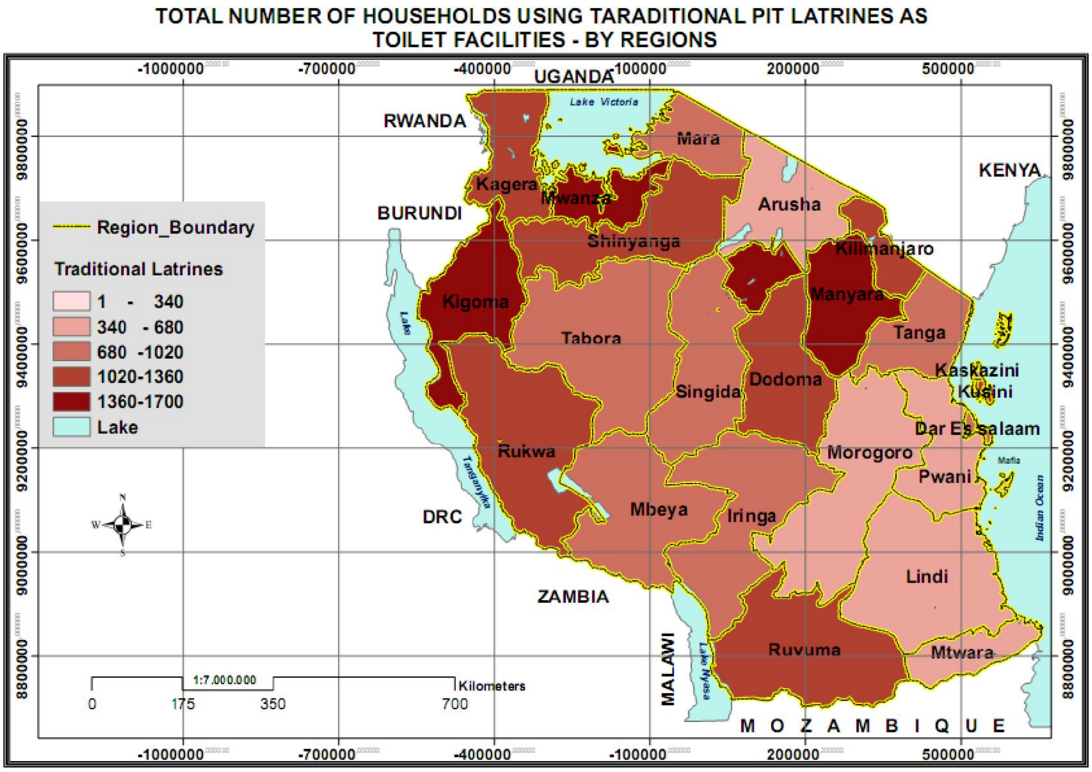

Figure 40. Spatial distribution of households using traditional pit latrines. Year 2008.

Various maps are resulting after performing spatial distribution as can be depicted from the (Figure 40). The analysis based on this results show that Kigoma, Mwanza and Manyara regions have higher number of household's lives close to traditional pit latrines followed by Kagera, Shinyanga and Ruvuma. In these regions malaria cases is very high. As can be seen from the map, the distribution of traditional pit latrines are distributed in every region in Tanzania mainland.

In Tanzania Zanzibar, Kusini region has shown with the highest number of household living close to traditional pit latrines followed by all other regions Kaskazini and Mjini Magharibi. The distribution of traditional pit latrine in Zanzibar and according to the previously observation with all other variable this variable seem to have more malaria impact in Tanzania Zanzibar than other variables (Figure 41).

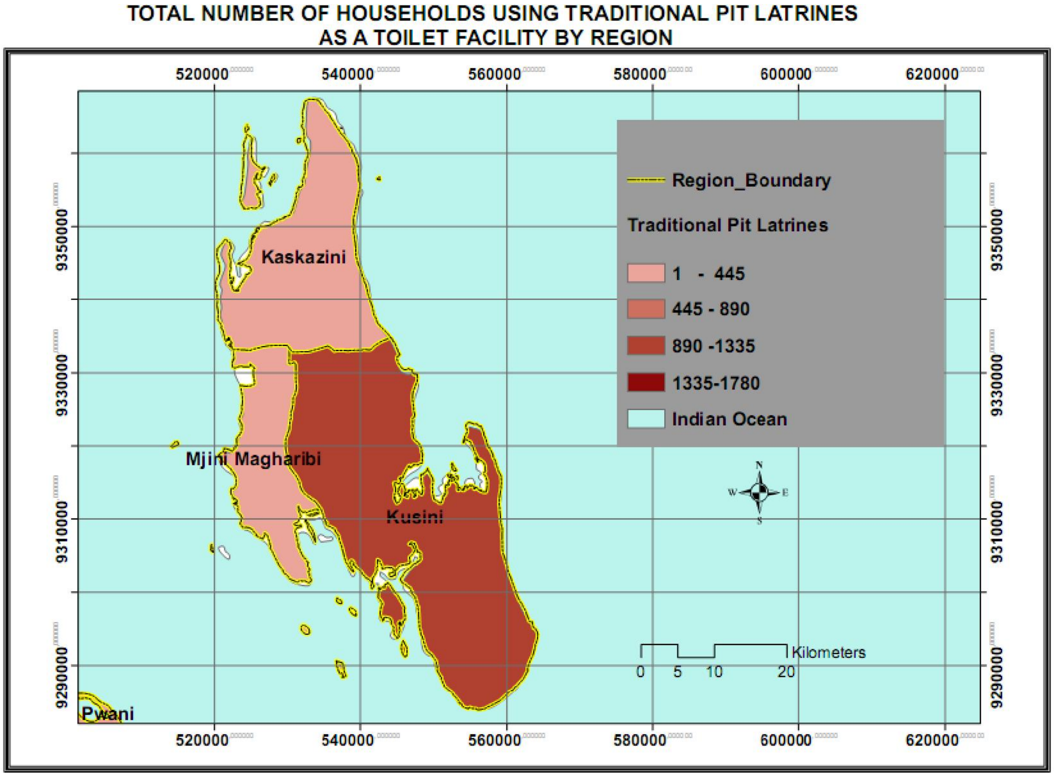

Figure 41. Spatial distribution of households using traditional pit latrines in Zanzibar. Year 2008.

4.8.3 Number of households use bush/ field as Toilet facility (FT41)

The variable was considered in this work with expect to have the information based on households using bush field as a toilet facility. The demerits of this kind of toilet facility is that it contribute to malaria disease as favours mosquito breeding since mosquitoes prefer dissolved organic matters to complete its life cycle.

Mwanza, Shinyanga, Mara, Dodoma and Tabora constitute high number of household uses bush field as toilet facility (Figure 42) and in these regions malaria incidence in very high (Figure 8 A). In Kilimanjaro and Dar Es Salaam regions has shown with fewer households using bush-field as toilet facilities. This variable does not contribute much to malaria transmission in these two regions even though malaria cases are very high especially in Dar Es Salaam region.

In Zanzibar it has shown that this variable are more distributed almost in all regions except Mjini Magharibi which showed low number of household using bush field as toilet facility this indicate that this variable contribute to malaria transmission in Zanzibar as well.

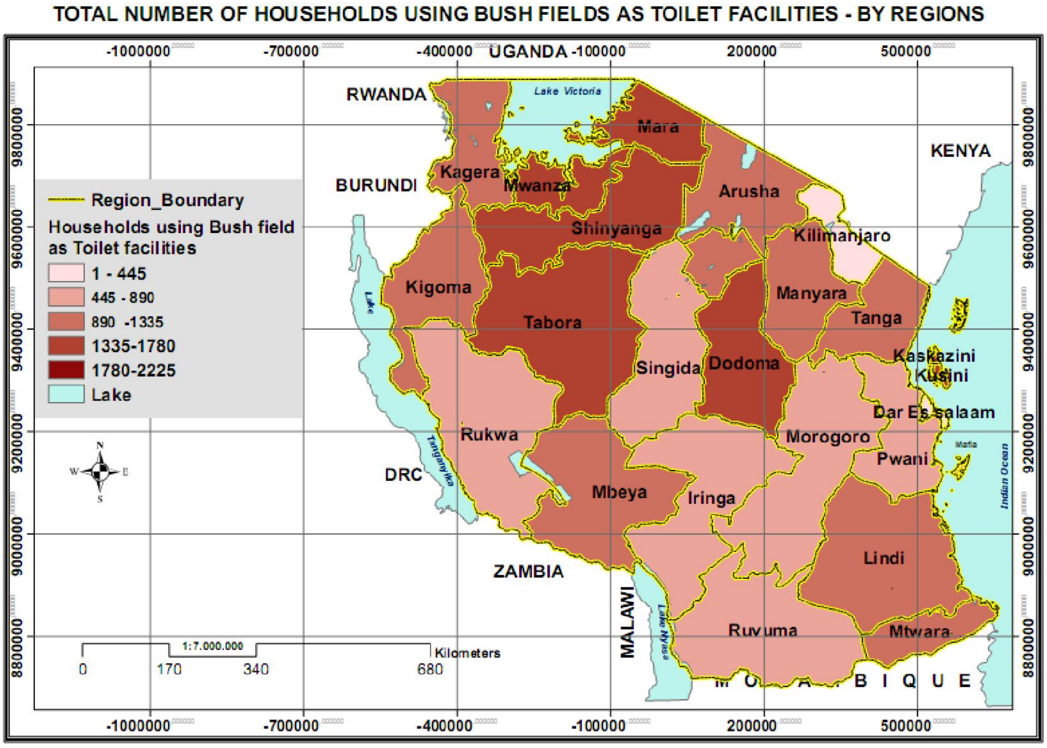

Figure 42. Spatial distribution of households using bush field as a toilet facility. Year 2008.

Further analysis is done by performing spatial overlay using both variables in the same region in order to identify the variable which transmits malaria mostly in each particular region (Figure 43) shows that traditional latrines dominates in most of the regions in Zanzibar.

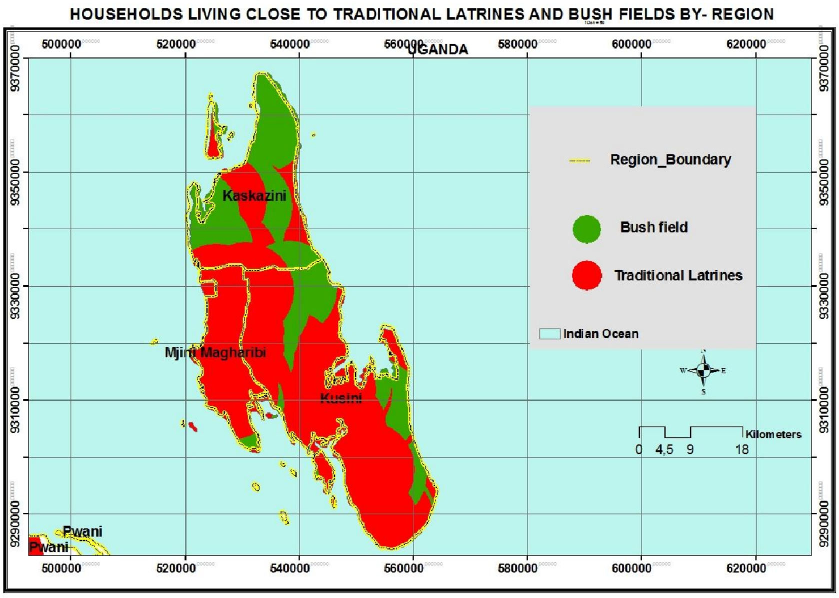

Figure 43. Spatial distribution of households lives close traditional latrines and bush field latrine. Year 2008.

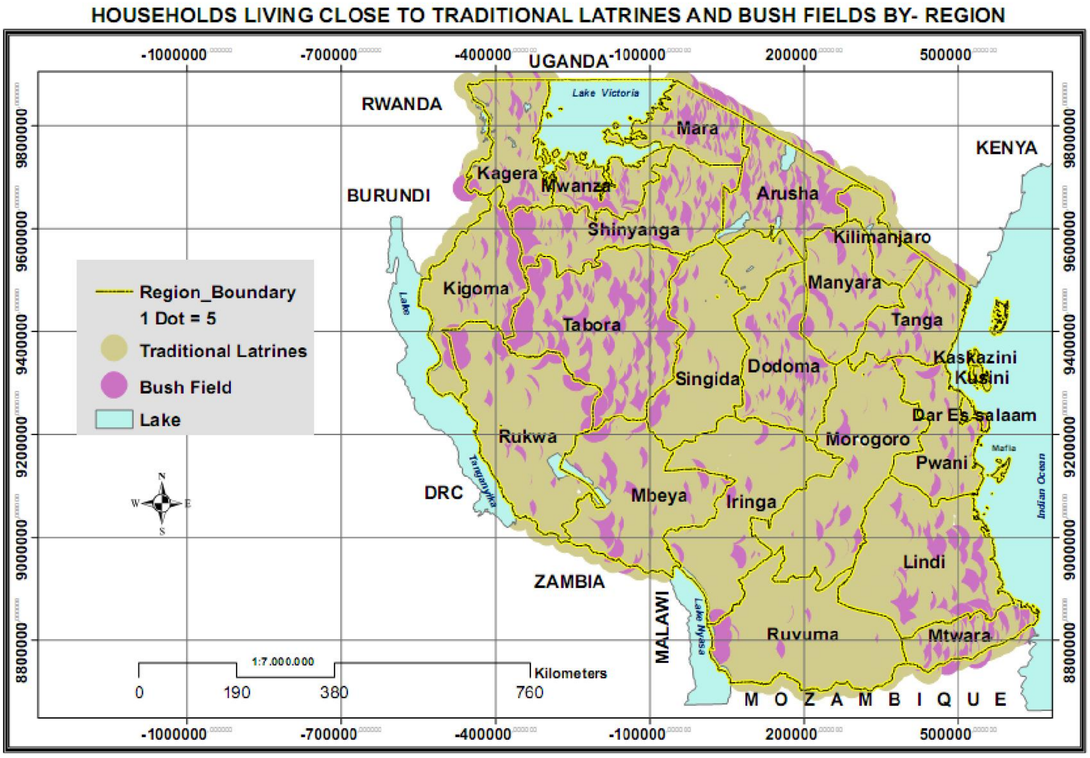

Figure 44. Spatial overlay of households lives close to traditional pit latrines and bush fields as toilet facilities. Year 2008.

According to the results (Figure **44**), traditional pit latrines dominate in most of the regions. In others regions like Tabora, Arusha and Singida regions have shown with high households using bush fields as toilet facilities because these regions have many tribes cattle keeping usually they live in the bush areas so this information reflect the reality. Among other regions Tabora region has high malaria intensity within the country while Singida and Arusha have low malaria cases. Therefore fighting against malaria in these regions should concentrate in both variables.

4.8.4 Number of households with Poor flush toilets (TF11)

This affect mostly people who are living in the urban areas especially in the cities, such toilet usually depend on physical location especially when flush toilets do not work proper and causes contaminated water to discharge within a plot or if some of the septic tank has linkage and allow mosquito to penetrate and multiply.

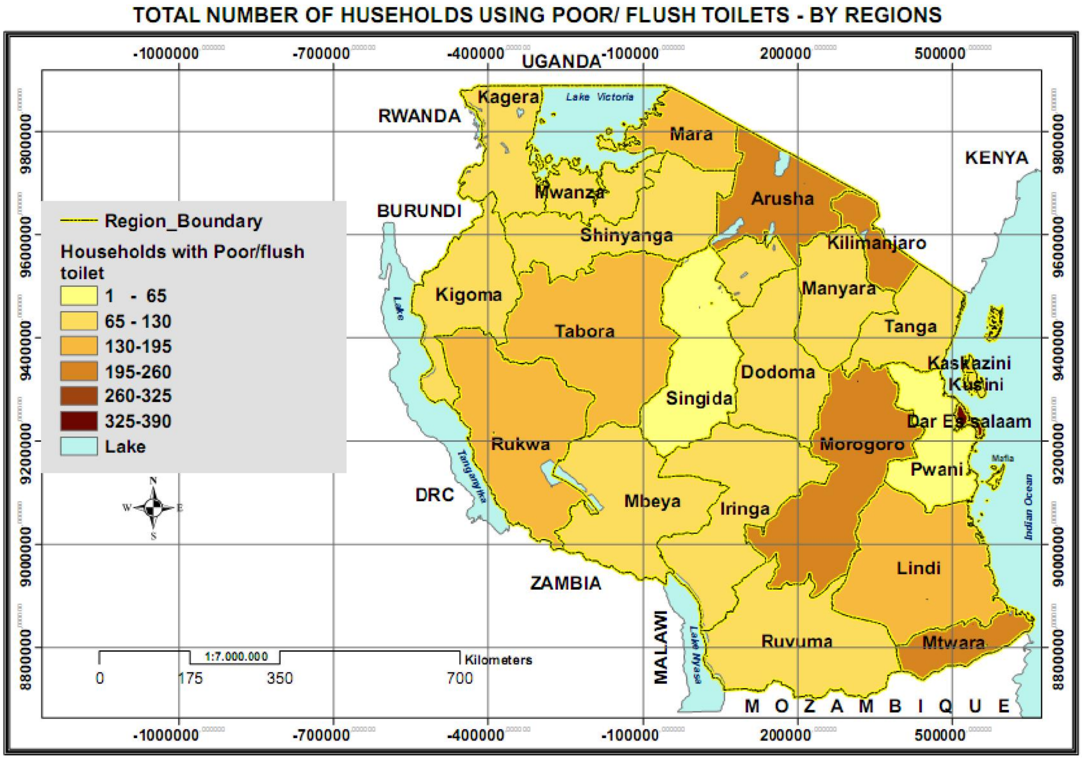

Figure 45. Spatial distribution of households with poor flush toilets. Year 2008.

Spatial Analysis on this variable show that Dar Es Salaam region is leading with high number of households using poor flush toilets and the region has shown previously with high malaria intensity (Figure 45), this variable should be regarded as contributing to malaria transmission in this region. The other regions with high number of households with poor flush toilets are Morogoro, Rukwa, Mtwara, Arusha and Kilimanjaro.

4.9 Utilization of R software

As mentioned previously in methodology part of this work R software is utilized fully in order to make a complete analysis of this study. Seventeen variables are assigned to R software for preliminary analysis. Principal component analysis method is considered in this operation and values are generated pertaining to each variable based on standard deviation, proportion of variance and cumulative proportion with the relation to the contribution to malaria epidemic as can be depicted from (Table 2).

components	Standard deviation	Proportion of Variance	Cumulative Proportion
Comp.1	2.5756848 1	0.4146345 0	0.4146345 0
Comp.2	1.7357583	0.1883036	0.6029381
Comp.3	1.4625175	0.1336848	0.7366229
Comp.4	1.19844918	0.08976753	0.82639044
Comp.5	0.82991212	0.04304713	0.86943758
Comp.6	0.74913412	0.03507512	0.90451270
Comp.7	0.74160850	0.03437395	0.93888665
Comp.8	0.53509629	0.01789550	0.95678215
Comp.9	0.48029943	0.01441797	0.97120012
Comp.10	0.42746968	0.01142065	0.98262077
Comp.11	0.318640329	0.006345729	0.988966495
Comp.12	0.280475426	0.004916654	0.993883149
Comp.13	0.24721392	0.00381967	0.99770282
Comp.14	0.165819367	0.001718504	0.999421323
Comp.15	0.085632514	0.000458308	0.999879631
Comp.16	0.0438851549	0.0001203692	1.0000000000

Table 2. Importance of Components.

Preliminary analysis is performed from PCA, followed by formulation of the equations which have to be used in order to calculate new principle component values related to malaria cases.

Table 3 show new computed values principal components. The values are determined based on the formula extracted as already shown in the methodology. These values are used during regression operation.

Component	Ys Values
Comp.1	0, 1845642865231
Comp.2	-1, 171066685152
Comp.3	- 0, 98231674622
Comp.4	1, 733034109788

Table 3. Computed new values principle components

4.9.1 Regression

Regression analysis is performed for all seventeen variables in order to determine a degree of association of each variable to malaria epidemic. New values are calculated based on calculated new principal components values (Table 4).

S/N	**Variables**	**Ys Values**
1	Mal_case	120226, 21171838128
2	Hbfs0	173, 549126893745696
3	Hbfs1	812, 3447115162412
4	Hsamil12m0	1659, 31518440374088
5	SW12	-31,505284002
6	SW11	134,7697870518651
7	Psuetb1	563,6914335134825
8	TF22	268,63849498694179
9	TF11	-44, 16574039487394
10	SW24	-4, 507689456798
11	SW41	-19, 98831223045173
12	SW42	-13, 5284121190821
13	Hsamil12m1	718,64219989142107
14	Psuetb0	288,16466409017845
15	SW43	0
16	SW41	-50,1227636767452
17	SW22,23	NULL

Table 4. variables and their respective values.

The analysis after regression show that there are four groups formulated from these results:

- First group represent a variable which shows the impact of malaria epidemic in the country,
- Second group represent the variables contribute to malaria epidemic but not very intensively,
- Third group represent those variables which contribute mostly to malaria at a large scale where the variable scored high values of malaria transmission and,
- Fourth group represent the variable which seems not to contribute but reducing malaria transmission in the country.

4.10 Summarized vector risks variables which contribute to malaria epidemic.

Vector risk variable which contribute mostly to malaria epidemic are determined from various approaches used in this work. Three groups of variables related to malaria cases are summarized and formed.
The following are groups and associated variables;

A. Households which are at high risk of malaria occurrence
This group is associated to the variables which contribute malaria transmission mostly to all regions and the associated variables area;

1. Number of persons without bed net for sleeping (Hbfs0)
2. Number of households lives close to the river or water stream (SW42)
3. Number of households lives close to the ponds, flood plain and lake (SW43)
4. Number of households did not spray against malaria over last 12 months (Hsamil12m0)
5. Number of households lives close to open well into yards or plots and public open well. (SW22, SW23)
6. Number of Households did not use insecticide bed net for sleeping (Psuebt0)
7. Number of households lives close to traditional pit latrines (FT22)

B. Households at risk of malaria transmission with specific variables
This group is at risk of malaria transmission associated to the variables which contributes malaria transmission to some of the regions. The associated variables are;

1. Number of households living close to neighbor having open well (SW24)
2. Number of household's lives with piped within the Yard or Plots (SW12)
3. Number of households living close to piped into dwelling (SW11)
4. Number of households lives close to natural spring water (SW41)
5. Number of households with Poor flush toilets (TF11)
6. Number of households use bush/ field as Toilet facility (FT41)

C. Households at low risk of malaria transmission
This is a group which is applying required means in order to reduce malaria transmission through mosquito bites. The associated variables are;

1. Number of persons with bed net for sleeping (Hbfs1)
2. Number of households sprayed against malaria in last 12 months (Hsamli121)
3. Number of household used insecticide bed net for sleeping (Psuetb1)

Note: in over all the entire variables which contribute mostly to malaria disease within the country and which have scored more value are, **Number of persons without mosquito bed net for sleeping** and **number of households did not spray against malaria over last 12 months**. As shown in Table 4.

Based on the analysis carried out with various tools used and the results obtained final spatial overlay is done restricted to; Households uses mosquito nets; indoor residual spraying and total deaths. The outcome of this, is the malaria map which shows spatial distribution of households at high risk of malaria occurrence (Figure 46)

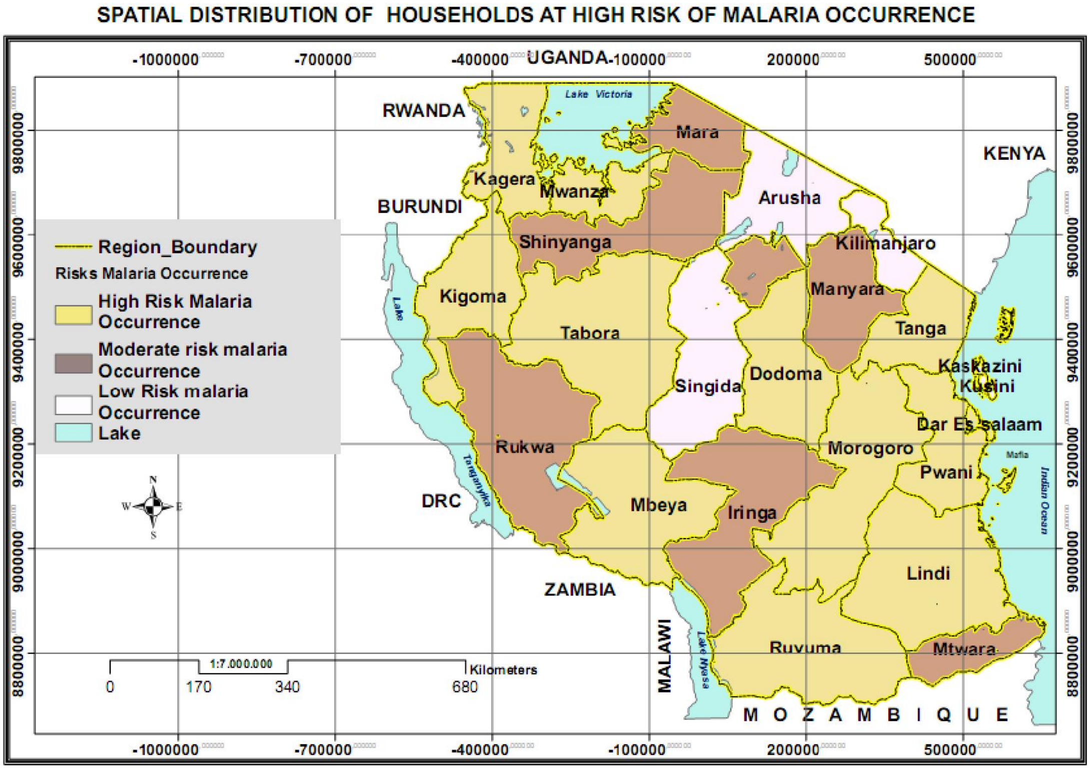

Figure 46. High risks malaria occurrences. Year 2008.

In Tanzania mainland 85% percent of total population of the entire country is at risk of malaria transmission disease while in Zanzibar most of the regions are at low risk of malaria transmission.

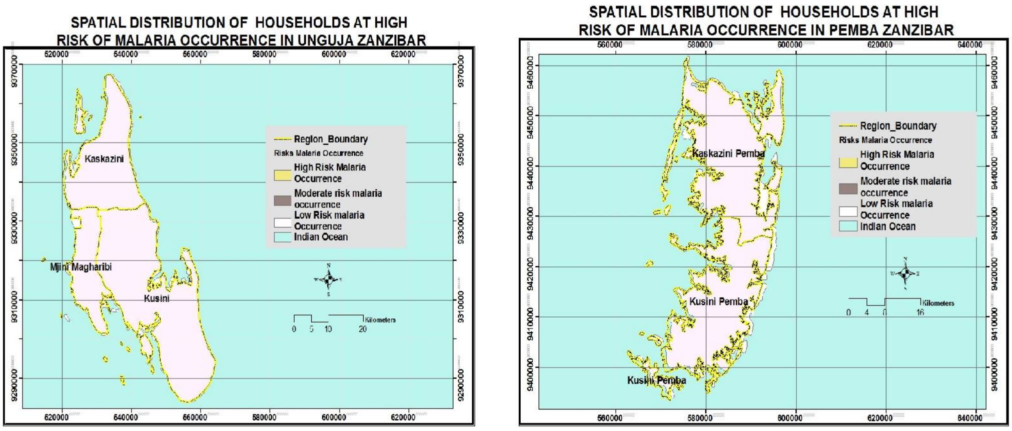

Figure 47. Low risks of malaria occurrences in Zanzibar. Year 2008.

In Figure 47 the spatial distribution of households at high risk of contracting malaria in Zanzibar is low and it significantly indicate that various measures have given priority in fight against malaria epidemic in Zanzibar.

5 CONCLUSION

5.1. Conclusion.

This work is of significance to provide vital information which is useful in fighting and reducing malaria transmission through mosquito bites. The study reveals that the risks of malaria are households without mosquito bed nets for sleeping and those without giving attention to indoor residual spraying. Use of insecticide bed nets, utilization and well implemented of indoor residual spraying will make it difficult for blood mosquito feeding to locate a human host as well as unusual high mosquito density.

Availability of crucial data based on smallest spatial unit with size of an average coverage of 80-100 households, locations of households living close to targeted proximity near the rivers, ponds, and other targeted area which seem to favour mosquito breeding are important data for further spatial analysis for malaria transmission .Also the Tanzania National Base maps of which most of them are out of date priority of updating those datasets regularly are vital information in fighting against malaria epidemic as will incorporate necessary information such as swamps, flood plains, vegetation cover and permanent water bodies which seems to be areas favouring mosquito breeding.

Furthermore, the government of Tanzania should give high priority in the establishment of NSDI (National Spatial Data Infrastructure), spatial data and SDI initiatives have potential applications to improve the current situation in fighting against malaria epidemic in Tanzania.

However, the goal of the National Malaria Medium Term Strategic Plan 2008–2013 is to reduce the occurrence of malaria in the country by 80%. This goal is in line with the Millennium Development Goals by 2015, in fulfilling this goal, the government should emphasize on use of insecticide bed net at large scale, and use of indoor residual spraying since through this work these two variables have shown to contribute mostly to malaria disease, without this concert this goal cannot be achieved.

5.2. Recommendations and final considerations.

In the future the government of Zanzibar should take a closer look to Kusini Pemba region which shows the highest number of households who does not use insecticide bed net for sleeping.

The Government of Tanzania should make sure that wide spread and use of insecticide-treated bed net (ITN) are introduced at large-scale in the entire country in order to reduce malaria transmission through mosquito bite.

The insecticide treated net should be provided for free to the children's below 5 years old and pregnant women who seems to be the most affected population groups from malaria epidemic. Since the logistic to reach these people might not be well rationalized, the distribution of the mosquito nets for the pregnant women who do never attend or go to the Dispensaries should be done at a village level based on common village markets.

The government must empathize and make sure that indoor residual spraying is fully utilized and well implemented in order to reduce and interrupt malaria transmission at least by 2015 half of the entire country should be covered as concur with MKUKUTA millennium goals.

Implementation and understanding mechanism of keeping clean all the surroundings, close to open well and public open wells, should be considered as well as households that living close to those area that seem to favour mosquito breeding must early be identified and insecticides should be done earlier before the beginning of rain season which usually starts in April to May, in order to reduce mosquito densities within indentified areas.

Cost and logistic difficulties inherent in mass distribution of insecticide bed net in Tanzania mainland require collecting, transporting and distributing the ITNs in some places which seems to be difficult to reach.

The Government of Tanzania should motivate the investors in the production of mosquito nets within the country rather than importing bed net from outside of the country.

The Government of Tanzania should think about subsidizing the cost of buying mosquito net in order to make it affordable to most of Tanzanians. This will be one of the ways to motivate individuals to buy the mosquito nets.

School curriculum and primary health care may take up on responsibility to educate the population on malaria issue this could help in the sense that people will know how to keep their environment clean and this will in turn prevent the mosquito from being abundant as mosquito use dirty environments and stagnant water for breeding.

It is important in the future that further study should be undergone in the utilization of geostatistical technique for the modeling and prediction of malaria epidemic in the country.

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ANNEXES

ANNEX A: Code developed to calculate Principle components

```
Bendata<-sqlQuery(channel=1,selectfrom[Sheet1$]

names(Bendata)<- make.names(names(Bendata))attach(Bendata)

str(Bendata)Bendata.pc<-princomp(Bendata[,-
c(1,2,7,16)],cor=TRUE)summary(Bendata.pc, loadings=TRUE).
```

ANNEX B: Equations to determine principle component related to malaria cases

Equations for determination of new principal components

Y1= 0.17(Mal - cases) + 0.25(Hbfs0)-0.338(Hbfs1) + 0.322(Hsamil12m0)-0.33(Psuetb1)-0.363(SW11)-0.176(SW12) +0.253(Sw41) +0.299(SW42)-0.219(TF11) -0.330(TF21) +0.179(TF22)-0.269(TF41)

Y2=0.307(Mal_case)–0.325(Hbfs0)-0.173(Hbfs1)-0.513(Psuetb0)+0.199(SW24)-0.156(SW41)-0.171(SW42)-0.210(SW22,SW23)+0.296(TF11)-0.1(TF21)-0.381(TF22)-0.33(TF41)

Y3= -0.376(Mal_cases)-0.203(Hbfs1)-0.270(Hsamil12m0)-0.203(0.82991212)-0.161(Psuetb0) +0.34(SW12)-0.486(SW24) +0.139(SW41)-0.495(SW22, SW23)-0.192(TF41)

Y4=0.195(Mal_cases)+0.209(Hbfs0)+0.101(Hbfs1)+0.193(Hsamil12m0)+0.119(Psuetb0)+0.242 (Psuetb1)+0.331(SW12)+0.370(0.48029943)+0.432(SW41)+0.186(SW42)-0.386(SW22,SW23)+0.326(TF11)+0.24(TF21)

ANNEX C: Code developed to calculate Regression of seventeen variable

```
summary(lm(Bendata$SW11~Bendata.pc$scores[,1]+Bendata.pc$scores[,2]+Bendata.pc$scores[,3]+Bendata.pc$scores[,4]))
```

ANNEX D: Regression formulated equation to obtain new score values

1. **Hsamil12m0=** 1259.15+195.57(Y1)-163.75(Y3) +117.26(Y4)
2. **Hbfs0=** 60.346+66.9(Y1)-86.123(Y2)
3. **Hbfs1 =** 1133.96-234.68(Y1)-119.76(Y2)-140.54(Y3)
4. **MAL_CASE** = 246148+30610(Y1) + 55399(Y2)-67896(Y3)
5. **Psuetb0** = 119.5(Y1)-170.7(Y2)-67.4(Y3)
6. **SW12** = 64.4(y1)-10.9(y2) +21(Y3) +20.5(Y4)
7. **SW24** = 20.6(Y1) +4.4(Y2)-10.9(Y3)-8(Y4)
8. **SW41** =108.3(Y1) +24.6(Y2) +42(Y3)
9. **SW42** = 186.5(Y1) +40.8(Y2)
10. **SW43** = 0
11. **TF11** = 69.8(Y1)-20.9(Y2) +28.3(Y3) +31(Y4)

12**TF22** = 1162.9(Y1) +58.7(Y2)-124.96(Y3)

13**TF41** = 417(Y1)-141.8(Y2)-175.6(Y3)-101.4(Y4)

14. **Psuetb1**= 523(y1)-160.6(y2)-77.7(y3) +117(y4)
15. **SW11** = 149(Y1)-91.6(Y2)
16. **Hsamil12m1** = 479.7(Y1)-363.4(Y2)-208.7(Y3)

ANNEX E: Total Variables

Total variables used in this work

Region	Pop_Reg	MAL_CASE	Hbfs0	Hbfs1	Hsamill12m0	Hsamill12m1	Psuetb0	Psuetb1	SW11	SW12	SW24	SW41	SW42	SW22,SW23	SW43	TF11	TF21	TF22	TF41
Dodoma	1,692,025	292303	722	651	1361	12	1231	142	25	48	5	87	277	320	11	13	6	1440	542
Arusha	1,288,088	220142	734	629	1337	26	1002	361	37	133	1	161	234	98	1	80	80	786	414
Kilimanjaro	1,376,702	139469	932	653	1558	27	1378	207	134	269	4	221	165	59		101	87	1378	19
Tanga	1,636,280	360248	726	772	1420	78	1145	353	79	79	32	152	322	237	26	25	61	1207	205
Morogoro	1,753,362	427185	380	848	1223	5	702	526	48	55	21	46	202	267	1	85	94	960	89
Pwani	885,017	373925	378	778	1149	7	717	439	9	27	11	33	27	457	11	9	32	999	116
Dar Es salaam	2,487,288	748889	164	1473	1522	115	576	1061	192	106	83	1	1	114	1	375	147	114	1
Lindi	787,624	123321	372	915	1287	1	867	420	16	41	3	39	103	626	1	47	18	986	229
Mtwara	1,124,481	217247	356	871	1227	1	889	338	22	36	12	21	176	569	1	67	32	689	318
Ruvuma	1,113,715	399679	537	1035	1556	16	1125	447	19	34	28	344	190	218	7	30	31	1457	54
Iringa	1,490,892	168452	986	390	1376	1	1241	135	9	43	7	313	259	142	1	29	49	1232	66
Mbeya	2,063,328	358110	722	689	1399	12	1124	287	63	59	11	86	274	889	1	23	69	1129	190
Singida	1,086,748	447919	767	709	1476	1	1278	198	3	6	6	61	278	354	223	8	17	1249	41
Tabora	1,710,465	367730	807	1105	1893	5	1757	156	41	29	37	4	68	1372	1	58	10	1155	681
Rukwa	1,136,354	148622	883	788	1664	7	1456	215	19	1	14	156	239	616	43	43	84	1446	98
Kigoma	1,674,047	234224	900	885	1764	21	1437	348	9	96	26	211	454	247	1	17	17	1562	184
Shinyanga	2,796,630	360597	857	1151	1999	9	1443	565	1	1	73	169	227	680	8	13	6	1440	542
Kagera	2,028,157	266230	772	890	1495	167	1377	285	3	7	12	178	463	329	28	23	35	1323	275
Mwanza	2,929,644	474607	485	1440	1925	1	1334	591	1	1	73	169	227	689	8	13	6	1678	567
Mara	1,363,397	169329	476	1480	1950	7	1234	713	11	20	10	164	306	628	366	49	103	1099	698
Manyara	1,037,605	101602	1132	528	1642	18	1470	190	5	42	14	170	335	265	54	17	17	1562	184
Kaskazini	136,639	1	271	1323	82	1512	982	61	315	62	1	1	11	231	1	39	106	872	577
Kusini	94,244	1	201	1444	31	1614	841	804	537	154	6	1	1	211	1	13	6	1440	542
Mjini Magharibi	185,326	1	266	1506	149	1623	874	898	762	64	29	27	1	142	1	381	334	1001	56
Kaskazini Pemba	136,639	1	572	3053	191	3434	2027	1598	615	77	11	1	1	859	1	144	286	985	2210
Kusini Pemba	175,471	1	341	3477	62	3756	1552	2266	904	186	5	1	8	457	22	112	697	1048	1953

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